

3. METHODS

a. At the time of each BSI data collection mission, blood was collected from a small group of 11th Armored Cavalry Regiment soldiers for this assay. Fifteen ml of venous blood was collected in vacutainers containing sodium heparin **anticoagulant** using aseptic technique. Specimens were given a code identification number, which was used consistently for all samples and BSI data for that soldier. This blood was transported on wet ice in less than 48 hrs from the data collection site (Germany or Kuwait) to **Microbiologicals, Inc.**, Rockville, MD, to the laboratory of Dr. David Jakobsen-Kram.

b. The peripheral blood lymphocytes **were** cultured in RPMI 1640 (GIBCO) medium supplemented with 15% fetal bovine serum, 1% penicillin-streptomycin, 1% phytohemagglutinin (**Burroughs-Wellcome**) and 10 $\mu\text{g/ml}$ **5-bromo-2'-deoxyuridine (Brd/U)**/ml (complete medium). Cultures were established by adding 0.6 ml of whole blood to 15 ml centrifuge tubes containing 9.4 ml complete medium. The cultures were then incubated at $37\pm 1^\circ\text{C}$ with 5% CO_2 in air for 68-70 **hours**. The treatment tubes were identified by sample ID number. Two hours prior to harvest, Colcemid was added to each culture at a final concentration of 0.1 $\mu\text{g/ml}$. After harvest **by** centrifugation, the cells were subjected to hypotonic swelling in 0.075M KCl and fixed in three changes of Carnoy's fixative (**methanol:glacial acetic acid, 3:1, v/v**) and then stored overnight or longer at approximately 0-6°C. The cells were suspended in a small volume of fixative and applied **dropwise** onto precleaned, wet slides. The slides were stained with Hoechst 33258 (5 $\mu\text{g/ml}$) for approximately 10 minutes, **mounted** in phosphate buffer, exposed to a black light lamp with 15 watt tubes for approximately 4-8 minutes and then rinsed and counterstained with 5% Giemsa solution at pH 6.8 for 6-10 minutes.

c. Cytogenetic evaluations were performed without observer knowledge of the cell source. Whenever possible, a total of 25 well-spread and well-stained second-division metaphases were evaluated per culture.

4. RESULTS.

a. A total of 61 blood samples were collected **pre-**deployment (Germany, 6 June 1991), 51 during deployment (Kuwait, 11 August 1991), and 36 post-deployment (Germany, 10 October, 1991). The number of collections varies due to **availability** of soldiers for phlebotomy at the times of the two later data collection missions. Summary tables of SCE count means follow.

b. Only 26 soldiers had values available for all three sampling points. Fifty soldiers had samples taken **PRE and DURING**, and 35 had samples taken **PRE and POST**.

c. DURING and POST SCE values differ significantly from PRE values, by paired t-tests. Non-parametric alternative testing and repeated measures analyses also yielded significant differences

Table SCE-1.

	PRE	DURING	POST
N			
50 ^a	4.33 ^b ± 0.53 ^d	5.12 ± 0.64	
35	4.38 ^c ± 0.55		5.28 ± 0.72

^a N varies due to differences in soldiers available for phlebotomy during each collection mission.

^b p < 0.0001 comparing PRE to DURING, paired t-test

^c p < 0.0001 comparing PRE to POST, paired t-test

^d Mean ± s.d. of individual means of SCEs per cell.

5. DISCUSSION

a. The summary comparisons described here show higher SCE frequency in Kuwait during deployment, and in Germany post-deployment, than the pre-deployment levels measured in a small group of 11ACR soldiers. These differences are numerically significant by paired t-test.

b. **Sister Chromatid Exchanges** probably represent sum effects of recent and near-past exposures. The half-life of peripheral lymphocytes varies; although many lymphocytes are in the circulation less than 30 days, some subsets of T-lymphocytes may persist for up to nine months (1). Similarly, although some studies show that SCE increases diminish within days after cessation of exposure to genotoxics, others show that SCEs remain elevated for up to eight weeks (2).

c. One interpretation of the SCE elevations detailed here would be that genotoxic exposures increased among these soldiers during the time spent in Kuwait. This broad statement does not discriminate among dietary, occupational, and ambient environmental sources of genotoxic agents.

d. The results described here likewise do not reflect any attempt to control for smoking, diet, or occupational exposures in the comparisons. This effort is in progress at the time of

this writing (NOVEMBER 93) and information gained therefrom will **be the basis for** amendments to this report.

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Final Rpt, Kuwait Oil Fire HRA No. 39-26-L192-91, 5 May - 3 Dec 91

ANNEX F-6

**POLYCYCLIC AROMATIC HYDROCARBON-DEOXYRIBONUCLEIC
ACID ADDUCT ASSAY**

KUWAIT OIL FIRES HEALTH RISK ASSESSMENT BIOLOGIC SURVEILLANCE
INITIATIVE

POLYCYCLIC AROMATIC HYDROCARBON (PAH)-DEOXYRIBONUCLEIC ACID (DNA)
ADDUCT ASSAY

Measurement of white blood cell polycyclic aromatic **hydrocarbon-DNA adducts** in **11ACR** personnel in Germany (5/91), Kuwait (8/91) and Germany (10/91)

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1. SUMMARY . Blood from soldiers of the **11th** Armored Cavalry Regiment was collected and examined for markers of exposure to polycyclic **aromatic** hydrocarbons. Collections were made before, during and after deployment to Kuwait from Germany. Assay results are consistent with low level exposures, and with environmental characterization data. Results also indicate the possibility that exposures to these compounds were lower in Kuwait than in Germany. **Some** further clarification may be possible after information on smoking, diet, and occupational exposures is examined.

2. BACKGROUND

a. Planning research for the environmental characterization of the Kuwait oil well fires indicated that polycyclic aromatic hydrocarbons (**PAH's**) would be predominant contaminants. PAH's include several potent human. carcinogens, especially **benzo[a]pyrene**. For these reasons, measurement of exposure to PAH's was included as an objective of the Biologic Surveillance Initiative (BSI). One method selected was immunoassay of PAH-DNA **adducts** in white blood cells. These **adducts** are covalently bonded complexes of PAH molecules with DNA. White blood cells provide an easily collected source of DNA which can be examined for **adducts**. Exposure to **PAHs** is reflected in and correlated with **adduct** levels (18).

b. Among immunoassays, the competitive benzo[a]pyrene-DNA enzyme-linked immunosorbent assay (ELISA) (1,2) and the ultrasensitive radioimmunoassay (USERIA) (3) have been used for determination of DNA **adducts** in human tissues. These assays were established for the detection of **benzo[a]pyrene** (BP)-DNA **adducts** and employed polyclonal antisera elicited against DNA modified with (\pm) -7 β ,8 α -dihydroxy-9 α ,10 α -epoxy-7,8,9,10-tetrahydro-**benzo[a]pyrene** (BPDE) (4). These antisera also recognize DNA modified with diol-epoxides of other polycyclic **aromatic** hydrocarbons (**PAHs**), including chrysene, benzanthracenes and benzofluoranthenes and the immunoassays performed with them compare the biological sample values with a (7R)-N²-{10-

[7 β , 8 α , 9 α -trihydroxy-7, 8, 9, 10-tetrahydro-benzo(a)pyrene]-yl}-deoxyguanosine (BPdG) - DNA standard curve. Because of the heterogeneity of human exposure there are likely to be multiple PAH-DNA adducts present on human DNA and because of the cross-reactivity of the antiserum, multiple adducts are probably being measured by this ELISA (5,6). Therefore, the ELISA results obtained by comparison of biological samples with BPdG-DNA are not precisely quantitative and are expressed as PAH-DNA adducts (7).

c. The data described here have been obtained using a more-sensitive adaptation of the original ELISA, the dissociation-enhanced lanthanide fluoroimmunoassay (DELFI) (9). The DELFIA, which has already been used in clinical practice (10) and DNA research (11), is based on the conjugation of a non-fluorescent form of a lanthanide label, europium (Eu), to a secondary immunocomponent. The lanthanide ion, bound to the solid phase, is dissociated into solution forming a highly-fluorescent chelate that is long-lived. The total chelate is then measured by time-resolved fluorometry (12), which eliminates interference by non-specific, short-lived background fluorescence. The specific fluorescent properties of the lanthanide end-point and a biotin-avidin amplification step are responsible for the increase in assay sensitivity observed here.

3. METHODS

a. At the time of each BSI data collection mission, blood was collected from a small group of 11th Armored Cavalry Regiment soldiers for this assay. Forty ml of venous blood was collected in vacutainers containing sodium heparin anticoagulant using aseptic technique. Specimens were given a code identification number, which was used consistently for all samples and BSI data for that soldier. This blood was transferred to polyethylene centrifuge tubes, and spun down at 1000G using a tabletop centrifuge. Plasma and red cell mass were pipetted off from buffy coats, and all three portions separately quick-frozen. The buffy coats and red cell mass were transported on dry ice to the Army Environmental Hygiene Agency, and still frozen, thence to Microbiologicals, Inc., Rockville, MD. Under the direction of Dr. David Jakobsen-Kram, DNA was extracted from the buffy coat cell contents.

b. The buffy coats of nucleated cells obtained from anticoagulated blood were resuspended in 50 ml polypropylene centrifuge tubes with 15 ml of nuclei lysis buffer (10mM Tris-HCl, 400 mM NaCl and 2 mM Na₂EDTA, pH 8.2). The cell lysates were digested overnight at 37°C with 1.0 ml of 10% SDS and 2.5 ml of a protease K solution (1 mg protease K in 1% SDS and 2mM Na₂EDTA).

c. After digestion, 5 ml of saturated NaCl (approximately 6 M) were added to each tube, the tube vigorously shaken for about 15 seconds, followed by centrifugation at 2500 rpm for 15

minutes. The precipitated protein pellet was left at the bottom of the tube and the supernatant containing the DNA transferred to another 50 ml polypropylene tube. Exactly 2 volumes of room temperature absolute ethanol were added to the tube and the tube inverted several time until the DNA precipitates.

d. The precipitated DNA was removed with a fire-polished glass Pasteur **pipet** or micropipet tip to a 15 ml polypropylene centrifuge tube containing 0.5 to 1 ml TE buffer (10 mM Tris-HCl, 0.2 mM Na₂EDTA, pH 7.5). The DNA was allowed to dissolve at least 2 hours at 37°C before quantitating.

e. An equal volume of chloroform was added to each tube containing the DNA in TE buffer. The tubes were rocked by hand until an emulsion is formed. The emulsion was centrifuged at 1600 x g at room temperature for at least 3 minutes. Using a transfer **pipet**, the upper aqueous phase was transferred to a fresh polypropylene tube and the volume transferred estimated. The interface and lower organic phase were discarded.

f. The concentration of monovalent cations was adjusted either by dilution with TE buffer (pH 8.0) if the DNA solution contained high salt concentration or by addition of 5 N NaCl solution to achieve a final concentration of 0.1 M.

g. Exactly 2 volumes of ice-cold absolute ethanol *were* added to the tube and the tube inverted several times until the DNA precipitated. The tube was stored at -20°C for 30 to 60 minutes to facilitate DNA precipitation if needed. The supernatant was discarded. The tube was inverted on adsorbent paper and remaining fluid aspirated in 'capillary tubes or micropipet tips.

h. The pelleted DNA was resuspended in TE buffer such that initially the concentration was higher than 500 µg/ml. The DNA concentration was determined by UV absorption at 260 nm. The DNA concentration was adjusted to 500 µg/ml by addition of additional TE buffer. The DNA samples were stored at 4°C until transferred to the Division of Cancer Etiology, National Cancer Institute, NIH, Bethesda, MD.

i. DEAE-Dextran, DELFIA microtiter plates (hard-frame, high-binding), DELFIA Assay Buffer, DELFIA **Eu-labelled** streptavidin, DELFIA Enhancement Solution, DELFIA Wash Concentrate-and Eu-labelled anti-rabbit **IgG** were purchased from **Wallac** Inc., Gaithersburg, MD. Biotinylated anti-rabbit **IgG** (H+L) was obtained from Vector Laboratories (Burlingame, CA). Calf thymus DNA, anti-rabbit **IgG** (whole molecule) alkaline phosphatase and 4-methylumbelliferyl phosphate were from Sigma (St. Louis, MO). [³H]-BPDE, the anti isomer (1.48 Ci/mmol) was purchased from the NCI Chemical Carcinogen Repository; NIH, Bethesda, MD. [³H]-BP (96 Ci/mmol) was obtained from Amersham (Arlington Heights, IL). Preparation of BPdG-DNA was performed as described

elsewhere (7); the modification levels were 28.1 pmole BPdG/ μ g DNA (9.37 adducts/ 10^3 nucleotides) for highly modified and 2.48 fmole BPdG/ μ g DNA (8.27 adducts/ 10^7 nucleotides) for low-modified BPdG-DNA. The rabbit polyclonal antiserum elicited against BPdG-DNA (antiserum 833) was prepared and characterized previously (4).

j. DELFIA microtiter plates (Wallac, Inc.) were precoated with DEAE-Dextran in 0.05 M carbonate buffer, pH 9.1 (60 ng/ml, 300 μ l per well) at 4°C for 24 hrs, then washed with PBS. Designated wells were coated with 0.1 ng of either unmodified DNA (for control) or highly modified BPdG-DNA standard (experimental). Both samples for coating were denatured before use by boiling for 5 min. Plates were dried by evaporation at 37°C overnight, and frozen.

k. At the time of assay, the plates were washed with PBS containing 0.05% Tween 20 (PBS-Tween). Non-specific binding sites were blocked by incubating the wells with 1% fetal calf serum (FCS) in PBS-Tween at 37°C for 1 hr. The plates were then washed again with PBS-Tween. Tubes for 1:2 serial dilutions of denatured BPdG-DNA standard competitor were prepared by dilution with denatured unmodified DNA to obtain a uniform per-well final DNA content. For appropriate comparison the standard curve wells must contain the same quantity of total DNA as the biological sample wells (between 1 and 35 μ g of DNA). Antiserum was diluted to $1:1 \times 10^6$ with 2% FCS in PBS-Tween. Equal volumes of diluted antiserum and standard competitor or biological sample DNA were mixed together, and 100 μ l was added to each well. After incubation at 37°C for 90 min the plates were washed with PBS-Tween. Reconstituted- biotinylated anti-rabbit IgG (1.5 mg/ml H₂O) was diluted to 1:2500 with 1% FCS in PBS-Tween, and 100 μ l was added to each well for incubation at 37°C for 90 min. The plates were washed once with PBS-Tween and once with DELFIA wash solution. Next, 100 μ l of a 1:2000 dilution of Eu-streptavidin in DELFIA Assay Buffer was added to the wells and plates were incubated at room temperature for 60 min. Then the plates were washed with PBS-Tween and DELFIA wash solution before 100 μ l of Enhancement Solution was added to each well. The plates were subsequently shaken on a plate rocker at room temperature for 2 hrs before fluorescence was measured by time-resolved fluorometry on a Wallac Inc. 1234 Research Fluorometer (Wallac Inc., Gaithersburg, MD). Variability within the triplicate wells of both standards and biological samples was improved when plates with the Enhancement solution frozen at -20°C for 12 hours before measuring fluorescence. Variability of the % inhibition in triplicate wells was 6.7% \pm 4.4% (mean \pm S.D., n=20).

4. RESULTS

a. Tables of summary data for the PAH-DNA adducts are presented below

b. Summary (unmatched) comparisons of all subjects (N ranges from 34-42) reveal **an** increase in **PAH-DNA adducts** from August (Kuwait) samples to October (Germany) samples. The measured difference is significant to the **p=0.0002** level. Measurements in **June** (Germany) average more **adducts** than those from August (Kuwait), but this difference is not statistically significant (**p=0.44**).

c. Comparisons of only subjects who gave two or **more** samples (**N=30; N=26**) also show an increase in PAH-DNA **adducts** from August (Kuwait) samples to October (Germany) samples. The measured difference is significant to the **p=0.0063** level. Again, a decrease is measured from June (Germany) to August (Kuwait), but the difference is not statistically significant (**p=0.46**).

d. Comparisons among only subjects who gave 3 matched samples (**N=22**) also show an increase in PAH-DNA **adducts** from August (Kuwait) samples to October (Germany) samples. The measured difference is significant to the **p=0.0009** level. A mean decrease is again shown from June (Germany) to August (Kuwait) but the difference is not significant **among** this small group (**p=0.25**)

e. These summary comparisons do not incorporate data **gathered** by questionnaire **about** smoking, diet, or occupational exposures.

Table DNA-1.

BSI DNA-PAH **Adduct** Assay
 White Blood Cell PAH-DNA **Adducts**, by Month **Tested**
 (For All Subjects)

Adducts/10 ⁸ nucleotides					
Month	N	Mean \pm SD	Median	Range	p value for difference ^a
June	42	2.62 \pm 3.33	1.7	0.4 - 17.3	0.44
August	34	2.52 \pm 4.14	0.6	0.4 - 17.6	0.0002
Over	38	4.06 \pm 3.20	3-5	0.4 - 17.8	

^a By Wilcoxon Rank Sum Test for unmatched group comparisons - *

Table DNA-2.

BSI DNA-PAH Adduct Assay
White Blood Cell PAH-DNA Adducts, by Month Tested

(For Subjects Who Gave At Least 2 Matched Consecutive Samples)

Month	N	Adducts/10 ⁸ nucleotides			p value for difference ^a
		Mean ± SD	Median	Range	
June	30	2.69 ± 3.64	1.3	0.4 - 17.3	0.46
August	30	2.27 ± 3.80	0.6	0.4 - 17.6	
August	26	2.05 ± 2.98	0.85	0.4 - 14.2	0.0063,
October	26	3.92 ± 3.49	3.25	0.4 - 17.8	

^a By Wilcoxon Signed Rank Test for matched group comparisons

Ta DNA-3.

BSI DNA-PAH Adduct Assay

White Blood Cell PAH-DNA Adducts, by Month Tested

(For Subjects Who Gave 3 Matched Consecutive Samples)

Month	N	Adducts/10 ⁸ nucleotides			p value for difference ^a
		Mean \pm SD	Median	Range	
June	22	3.12 \pm 4.09	2.25	0.4 - 17.3	0.25
August	22	1.63 \pm 1.76	0.65	0.4 - 6.3	0.0009
October	22	3.96 \pm 3.49	3.25	0.4 - 17.6	

^a By Wilcoxon Signed Rank Test for matched group comparisons

5. DISCUSSION

a. The summary comparisons described here are consistent across various groupings in showing a trend of higher levels of PAH-DNA **adducts** for samples taken Germany than in Kuwait, both before and after the June, 1991 deployment to Kuwait. Differences from August (Kuwait) to Germany (October) are all numerically significant.

b. The half-time in vivo for **adducts** such as these is somewhat unclear. Many cells are short-lived, but some lymphocytes are long-lived and may contain persistent **adducts**. Thus, these PAH-DNA **adduct** measurements probably reflect both current and past exposures (18).

c. In comparison, foundry workers, whose ambient exposures were up to 60 ng **benzo[a]pyrene/M³**, mean PAH-DNA **adduct** concentrations ranged from 1-35 **adducts/10⁸** nucleotides, with a mean of about 10 (18). The mean **adduct** levels in this sample range up to 17.8 **adducts/10⁸** nucleotides, with a mean of about 4. This implies an exposure of far lesser magnitude than 60 ng **benzo[a]pyrene/M³**, consistent with environmental sampling data from the U.S. Army Environmental Hygiene Agency's environmental characterization of the Kuwait oil well fires.

d. The results described here do **not** reflect any attempt to control for smoking, diet, or occupational exposures in the comparisons. Dietary sources of **PAHs** may be important in many settings. In specific, supplemental questionnaire data regarding diet, smoking, and occupational exposures must be related to these data in order to consider the results final. This effort is in progress at the time of this writing (NOVEMBER 93) and information gained therefrom will be the basis for amendments to this report. A continuing discussion among all contributors to the BSI may shed more light on these findings, as all parties have ample opportunity to evaluate separately prepared information.

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ANNEX F-7
STUDY PLAN

Plan for the Biologic Surveillance Initiative, Kuwait Oil Fires Health Risk Assessment.

1. Project title:

This project will be known as the Biologic Surveillance Initiative, Kuwait Oil Fires Health Risk Assessment. It will be referred to in this document as the BSI.

The BSI is properly regarded as medical or epidemiologic surveillance, as defined in AR 70-25, DODD 3216.2, and 45 CFR 46, subpart A, Sec. 46.102.

This project is exempt from AR 70-25, as set forth in Appendix F., paragraphs a. and c. of that regulation.

2. Investigators

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3. Location of surveillance project:

This surveillance project will be **directed** by personnel from the USAEHA. Aberdeen Proving Ground, MD, 210 1 O-5422.

Questionnaire administration and sample collection will take place in Germany. and Kuwait City, Kuwait. This will include serving Medical Treatment Facilities. e.g., Frankfurt Army **Medical** Center, Frankfurt, Germany, and field unit medical facilities, such as Battalion Aid Stations.

Laboratory analyses will be performed at:

AFIP:	Trace metals analyses
CDC:	Volatile Organic Compounds
JHU:	DNA adducts
MI:	Sister Chromatid Exchange Frequencies
NCI:	DNA adducts
USAEHA:	1 -pyrenol assay

Data **entry** and analyses will be performed at the USAEHA. WRAIR. **AFIP**, JHU. CDC and the NCI.

4. Time required to complete:

Sample collection and questionnaire administration will begin about 01 June 1991, and continue through December 1991. Laboratory processing and analyses of specimens will continue through March 1992.

Data entry will begin upon receipt of the first laboratory test results, and continue through May 1992. **Preliminary reporting** of results may be possible as early as March 1992. Complete **reporting** with relevant **interpretations** is anticipated to be possible by July or August 1992.

Integration of BSI data with Health Risk Assessment interpretation and reporting may be accomplished by October or November 1992.

5. Introduction

5-a. Synopsis.

Oil well fires burning in Kuwait since mid-February 1991 have introduced tons of combustion products into the environment of the Persian Gulf region. U.S. forces have operated in this polluted region during that time. Although the environmental and human health effects of these fires are largely unquantified, concerns about the possibility of cancer, respiratory effects, heavy metal poisoning and increased incidence of infectious disease, are justified on theoretical grounds.

The US Army Environmental Hygiene Agency (USAEHA) is conducting Health Risk Assessment (HRA) of the oil well fires' contaminants in response to tasking by the Joint Chiefs. This will quantify long-term risk of adverse health effects for US troops who have served in the Persian Gulf/Kuwait Theater of Operations (KTO). HRA's, however, employ environmental data, and extrapolate by modelling to human exposure. Typically, the health effect information used to calculate risk is taken from existing literature, and is not evaluated concurrently. Serious questions may remain unanswered regarding the medical effects of these contaminants. The scientific community, as well as the public, may doubt the appropriateness of assumptions that are made when the HRA process is applied to the oil fires scenario.

To strengthen these assumptions, biologic surveillance of a group of soldiers deploying from Germany to the Kuwait Theater will be conducted. The cohort may be exposed to smoke and other products from the oil well fires. This exposure will be objectively verified and *quantified* by environmental monitoring located at the same site as the soldiers in question. The end result will be a measurement of ambient contamination that is linked with measurements of biologic exposure and physiologic effects, all derived within the same microenvironment.

The goal of the Biologic Surveillance Initiative is, therefore, to measure objectively any level of intoxication or *discernible* change in health status in this body of troops which can be *associated* with oil well fire pollution.

The BSI involves only minimal risk to all participants in the surveillance population (SP). IAW AR 70-25, DODD 3216.2, and 45 CFR 46, subpart A, Sec. 46.102. The techniques involved are health care surveillance from MTF logs, questionnaires and diaries, *spirometry, urine* collection, and obtaining blood specimens by venipuncture (maximum of 45cc per collection). This will occur no more frequently than every six weeks, and no more than four times per individual.

5-b. Military and medical relevancy.

The significance of the contamination occurring in the Persian Gulf is not inapparent even to the casual observer. Between 500 and 700 *Kuwaiti* oil wells have been set on fire, resulting in a massive amount of air pollution, the scale of which has not been seen before. The fires inject thousands of tons of matter into the air over Kuwait and its neighboring countries every *day*. To date *only* a fraction of these wells have been extinguished. It is estimated that two to five years will be required to extinguish all of the fires.

Although the environmental and human health effects of these fires are **largely** unknown, **there** are theoretical concerns regarding the possibility of carcinogenesis, respiratory effects, heavy metal poisoning, increased incidence of infectious disease, and other health effects. While preliminary data **collected** and analyzed by the U.S. Environmental Protection Agency (EPA) indicate that these effects are likely to be minimal and transient, this is not known with certainty.

Efforts to model the long-term human health risk has been ongoing. Use of models to project health effect is at best a contentious endeavor, because all models depend heavily on assumptions, many of which must be extremely conservative and overstate risk when empiric data do not exist. Much of any HRA depends in large part on estimation of effective dose at appropriate target sites within the human body. Typically, to help define risk, models use estimates of environmental concentrations along with animal data to define the probability and quantity of absorption and the **ultimate** effect at sites of biological activity. The **end** product may easily over- or understate risk by orders of magnitude. The actual health effects resulting from exposure to toxicants are related to many factors (concentration of toxicant, route of exposure, duration of exposure, individual susceptibilities and interactions among toxicants). Thus, it is virtually impossible to model risk without expressing it in the most conservative terms.

As the preceding paragraphs imply, it is the accurate and precise measurement of the exposures in question which gives scientific validity to the product: a calculated quantity of risk to health that is associated with the contamination. When **the** exposures **are** multiple, the complexity of the task is far greater. A literature review has indicated that there may be a wide variety of **toxicants** found within the environmental pollution. Accordingly, the U.S. Public Health Service has recently issued a health advisory for **Kuwait** and Saudi Arabia. The statement indicates that the major toxicologic concerns are carbonized **particulates**, carbon monoxide, carbon dioxide, sulfur oxides, oxides of **nitrogen**, polycyclic aromatic hydrocarbons, sulfuric acid, acrolein, hydrogen sulfide, ozone, trace metals, numerous other aliphatic and aromatic hydrocarbons, and other moieties not specifically noted.

The **USA-EHA** health risk assessment, will derive from a vast quantity of environmental monitoring now underway. Air and surface soil are being sampled at ten primary locations in the Kuwait Theater, including Saudi Arabia. In addition to this ambient monitoring, personal sampling at a number of locations is also being conducted. The product of this enormous undertaking will be a comprehensive base of exposure data.

However, there are no empiric biologic data of exposure yet being obtained. Although such data **collection** is not usual in the HRA process, it is germane to this situation for **several** reasons. First, there is a relatively small body of literature on the human health effects of products of freely combusted petroleum. Not only are these effects sparsely investigated, but the exact chemical makeup of oil well fire effluent is not well-determined. Objective biologic data may refute or substantiate any number of heretofore accepted constructions of probable outcome. This is especially true because this surveillance initiative will sample from a **human** population, in distinction to the largely **animal-based** toxicology literature.

Second, the event in question, the contamination of such a **large** region from some **500+** burning oil wells is, perhaps, unique in human history. Certainly it **is** the largest-scale event for which the Department of Defense (DOD) has ever directed that HRA be performed. The modeling which will be involved in **the** calculation of exposure from ambient sampling concentrations, **and** thence the **health** risk, will likewise be of a scale not **to** be executed. Thus, any potential errors could also have a great magnitude. For this reason, it is critical that **all** modalities which will contribute to the validity of the work are exercised to whatever extent feasible and available.

Third, the exposure of the soldiers and other persons in the KTO is ongoing, even as the environmental monitoring is being accomplished. This is unusual among many of the **events** and sites where **HRA's** have been done in the past. Much HRA work is done only predictively or retrospectively regarding true exposures. The opportunity to simultaneously and objectively evaluate contamination and exposure is thus rare.

Thus the surveillance **will:** quantify the potential exposure to numerous toxins for a specific body of soldiers now in theater, allow **better** estimates of exposure for all US forces in Southwest Asia since the **fires** began to burn, and contribute to knowledge about the indigenous **population's** exposures. Accurate measurement of exposure will allow intelligent prediction of future health effects in those exposed (health risk assessment). This may guide further long-term surveillance, or a registry of those exposed for health effect tracking, for US military personnel, DOD-employed or contracted civilians, or even the population of Southwest Asia.

5-c. Objectives.

There are two objectives of the Biologic Surveillance Initiative (**BSI**). First, objective measurement of troops' exposure to environmental contaminants, as well as measures of effect such as pulmonary function tests, are true tests for biologic events. These may be brought about by contact with oil well **fire** products- Some of these products may have long-term adverse health effects. positive findings in the surveillance population may allow the early identification of needs for health care or further surveillance.

Second, the quantitation of exposure to putative oil well **fire** products by measuring markers of exposure or internal dose allows validation of the health risk assessment (HRA) process in the translation from measured environmental concentrations of contaminants to **modelled** human exposure. The objective biologic measures of exposure obtained through the BSI will **serve** to corroborate or counter the **modelled** exposures derived from environmental concentration measurements alone. This will increase the validity of the entire health risk assessment.

A. **further** breakdown of these aims is possible. The ability to watch over the health of troops is a primary concern of the Army Medical Department. This will be accomplished by several means.

1. Use of Medical Treatment Facilities (**MTF's**) by the body of soldiers in question will be tracked and recorded. This provides a picture of any changes

in health effects during deployment to Kuwait and in the succeeding period.

2. **Self-reported** changes in health **status** will be measured through questionnaires. This will afford a greater depth of investigation than allowed by tracking **health care access**, but will address many of the same questions. In addition, this modality allows a **measurement** of subjective events not otherwise discernible. Questionnaire analysis also brings an **important degree** of validation to the process.

3. Most of the tests _{to} be performed on blood and urine are both sensitive and specific, thus allowing concrete description of this population's **exposure to** a number of potential **contaminants**. Some of the chemical substances expected _{to} be present in the oil fires' products have known human health effects. These include mucosal and dermal irritation, pulmonary irritation, neurotoxicity, hematopoietic tissue effects, and simple and chemical asphyxiation. Others have documented effects on animals or positive results in other tests that indicate that they may be toxic _{to} humans, including findings **of** genotoxicity and carcinogenicity. Although no direct predictions will be possible for any one soldier's health, testing may reveal significant exposure to certain toxins. If this is the **case**, future work to safeguard the health of those exposed will have been facilitated. Such safeguards might include registry of exposed individuals through either the US Agency for Toxic Substances Disease Registry, or the Armed Forces **Institute** of Pathology Registry of Pathology and Toxicology. Alternatively, further medical surveillance of groups known to have been exposed in similar fashion **could** be directed. This could take the form of periodic medical tests related **to** the **particular** risk identified.

The second component aim of the BSI can be subdivided as well. Again, this is to contribute to the validity of the overall health risk assessment.

1. The blood, urine, and other laboratory **tests** conducted will represent actual exposure to many different chemicals. Some of these tests are precise enough to allow extrapolation from the test result to what **the** ambient exposure was for the group. This estimated range of exposure concentration can be directly compared with estimates derived -from the environmental measurements performed simultaneously with the blood tests. This affords a rare opportunity for' checking the validity of both processes.

2. Likewise, the results of these blood -and urine tests provide an opportunity to validate the modeled exposures **derived** from environmental measurements, meteorologic modeling, and information regarding troop locations and strengths. This will increase the **precision** of the calculated risk. Also, the bounds of **the** assessed risk which are used for planning or any actions related to the **contamination** could more closely approach actual risk; i.e., increase the **accuracy**. The quality and meaningfulness of the overall **HRA** should thus be greatly **enhanced**.

3. There is another benefit of objective data reflecting environmental **exposure**. The environmental monitoring being performed, although conducted at the state of the art, may not detect every possible contaminant. Some of the biologic tests which will be performed are very nonspecific. That is, they represent **effects** which could occur from any one of many different

exposures or intoxications. If negative for findings of actual exposure, these tests would address contentions that there were exposures to substances **not** directly quantified by the environmental monitoring.

5-c-1. Project design.

The design of the BSI is that of occupational medical surveillance of a fixed cohort of soldiers. This project does not include any follow-back investigations, nor does it entail long-term follow-up of any members of the SP.

5-c-2. Type of subject population observed.

The surveillance population is the 2500-3000 soldiers of the 1st Armored Cavalry Regiment deploying to Kuwait on or about 10 June 1991.

5-d. Status.

The health effects of the Kuwait oil fires' contamination has been of worldwide concern since their ignition. To date, only **limited** work has been done to elucidate this area.

The US Environmental Protection Agency has sampled for **criteria** pollutants, and found that no significant acute health risk is apparent.

The US Public **Health** Service has made **observations** in and around the area of contamination, and issued a health advisory warning that hypersusceptible persons for example asthmatics, or those with heart disease, may suffer adverse health effects during peak exposures.

US Navy clinical medical surveillance does not reveal an **association** of exposure with acute health effects to date.

To date, much of the remaining US literature relevant to this contamination event includes only models and suppositions.

Toxicologic literature exists for many of the several expected components of **the contamination**, and **will provide** a basis for the overall health risk assessment process underway at **the USAEHA**.

In contrast, the BSI **will** attempt to detect of acute health effects in a cohort, as well as provide empiric data to allow long-term health, risk assessment. This cohort has **the** distinguishing characteristic of being measured pre- and post-exposure to potential toxins.

5-e. Bibliography.

Attached as Appendix A.

6. Plan:

6-a. Number of subjects

6-b. Age range.

6-c. Sex.

6-d. *Inclusion criteria.*

6-e. *Diagnostic criteria for entry.*

6-f. *Evaluations before entry.*

6-g. *Exclusion criteria.*

6-h. *Source of subjects.*

The SP numbers approximately 2500-3000 soldiers who may range in age from 18-65. The SP is a healthy population which is predominantly male. All these soldiers have undergone pre-deployment health record checks and immunizations prior to leaving Germany. There are no exclusion criteria, save that persons who are acutely ill with upper respiratory complaints will not undergo spirometry. Soldiers of the 11th ACR deploying from Germany to Kuwait with their unit on or about the 10 JUNE 1991 will all fall under the umbrella of this surveillance initiative.

6-i. *Subject identification.*

Surveillance population members will be identified **internally** to the **data** collection process by social security number and by name, as well as by **military** unit. Each questionnaire, biologic specimen, and test result will be given a code number for identification. The code keys will be maintained separately from data files, and under controlled-access, locked storage. Primary data instruments such as questionnaires, which may retain inherent **identifiable** material, will be maintained in locked storage until five years after all reporting from this initiative is complete. Such instruments may be maintained for a longer period, but will still remain under controlled-access conditions.

All reporting will be exclusive of personal identifiers. All reports, internal documents, logbooks, rosters, magnetic media, lab results, diaries, questionnaires, memoranda and any other instruments which may contain identifiers or potentially identifiable information regarding members of the surveillance population will be maintained in locked storage at all times. All records will be kept for a minimum of five years **after the** completion of all **BSI** work and reporting. At such time as it is **elected** to dispose of any instruments which may contain identifiable information, destruction will be assured before disposal. Magnetic media, if any are disposed, will be erased **IAW** Department of Defense data encryption standards.

Because of the potential for future work on adverse health effects, a repository for permanent records of this population will be established at the direction of the Office of the Surgeon General, US Army, and under the aegis of the WRAIR and the USAEHA. This will be a controlled-access storage, and will remain coded, with data separate from identifiers.

6-j. *Analysis of risks and benefits to subjects; risks to those conducting research.*

6-k. *Precautions to be taken to minimize or eliminate risks to subjects and those conducting the research.*

The benefit to the surveillance population members is twofold, **and** has been described in the objectives section: early identification of previously unknown or unexpected adverse health effects of oil well fire pollution; and

improved ability to develop a **risk** assessment to **be** used in risk communication to individuals undergoing this or similar **exposure**. The risks to the SP **members** are comparable to those encountered in a routine physical examination including phlebotomy and spirometry. Other risk may be presented by use of identifiers in data handling internal to the BSI, but this will **be** minimized by the privacy safeguards previously described.

Risks to the investigators include those of handling biologic fluids. Universal precautions will be employed. As well, there will be the risks of travel, and of movement to an active theater of operations. These will be minimized by appropriate theater policies and safe operating procedures in the KTO.

6-l. Corrective action necessary.

6-m. Special medical care or equipment needed for subjects admitted to the project.

None identified.

7. Evaluations made during and following the project:

7-a. Specimens to be collected.

7-b. Clinical assessments.

7-c. Vital signs.

There are eight methods through **which** the health status and exposure experience of this cohort will be measured. These are:

Medical Treatment Facility (MTF) / Health Care Access **tracking** and **surveillance**.

Questionnaires.

Pulmonary Function Tests.

Trace metals analysis (**peripheral** blood and urine).

1 -Hydroxy Pyrene assay (urine).

Volatile Organic Compounds (VOC's) (plasma).

Sister **Chromatid Exchanges** (**peripheral** blood lymphocytes).

DNA adducts (**peripheral** blood lymphocytes).

Each is discussed in depth here.

Measures of health effect

MTF surveillance.

All the deploying members of the **11ACR**, some **3000+** soldiers, will receive health care in the KTO through unified facilities. This will be through the organic medical element of the **11ACR**. As well, the supporting backup facility, the 912th MASH, is co-located with the **11ACR base** camp at the **Doha industrial** complex, called Camp Thunder Rock. This results in a centralized source for all health care for the entire SP.

A surveillance log will be provided to the MTF supporting the **11 ACR**. This is a daily log of the treatment facility activity with categorized case

numbers and dispositions **by** diagnostic group. These will be executed on a daily basis by the medical personnel of the MTF. Collection of the logs will follow deployment. The log sheets are attached in Appendix B.

Questionnaires.

Questionnaires will be administered to as large a **body of the 11ACR** as can be accomplished prior to departure from Germany. This pre-deployment questionnaire will address:

- . general demographic characteristics
- . medical history, including family history, social history, medications and allergies, smoking and passive exposure
- . reproductive history and pregnancy outcome
- . complete occupational history including description of current Job; solvents and materials handled with frequency and duration

Questionnaires will also be administered to soldiers who **undergo** other tests while in Kuwait. These interim questionnaires will contain some repeat questions for validation, and will otherwise address many of the same health questions asked on the predeployment questionnaire. Special reference will be made to events which have occurred since deploying to Kuwait. The predeployment and interim questionnaires will take about 15 minutes to complete.

Some soldiers will undergo spirometry for the first time in this surveillance initiative **after** deploying to Kuwait or even upon return to Germany. These individuals will complete a slightly **modified** questionnaire, which will obtain the brief medical history elicited in the predeployment questionnaire. Questionnaires are attached in Appendix B.

Preparation of questionnaires and description and analysis of questionnaire data will be accomplished jointly by USAEHA, Dr. Melissa McDiarmid, and WRAIR Division of Preventive Medicine.

Pulmonary Function Tests.

Spirometry will be performed on approximately **250** individuals in the SP prior to leaving Germany. The outcome measures specifically to be recorded will be forced vital capacity (**FVC**) and forced **expiratory** volume at one second (**FEV₁**). These measurements will be taken on pneumotach-type portable spirometers. Spirometry will take approximately 15 minutes per test.

Spirometry will be performed on the same troops after their return to Germany. It will also be performed on as many of the same troops as possible during their time in Kuwait. All who have spirometry either pre- or during deployment will be sought for follow-up **after** return to Germany.

Results of spirometry data will **be** described and **analyzed** jointly by USAEHA and WRAIR Division of Preventive Medicine.

Procedures for spirometry are attached as Appendix C.

Direct Measures of Exposure.

Trace Metals Analysis (TMA).

Peripheral blood and urine will be **collected** for TMA from approximately **250** individuals in the SP. This will be performed prior to deployment, **on** a subset of these 250 twice during **the** deployment, and again **after** the SP returns to Germany. This analysis will be performed at the Armed Forces Institute of Pathology (AFIP). **The** senior investigator who will oversee these **analyses** is Victor F. Kalasinsky, Ph.D.

Results of this assay will be **described** and analyzed jointly by AFIP, USAEHA **and** WRAIR Division of Preventive Medicine.

Description of all blood collections involved in the BSI is attached in Appendix D. Description of urine collection procedures is attached as Appendix E. Protocols for the TMA are attached as Appendix F.

1-Hydroxy Pyrene (1 HP) Assay.

1-Hydroxy Pyrene is a very well-documented, available assayed marker for exposure to **polycyclic** aromatic **hydrocarbons**. The **correlation** of this marker with environmental exposures approaches unity. The incorporation of this assay in the BSI affords a sensitive and specific direct look at exposure to a class of compounds clearly associated with several **forms** of cancer.

Urine will be collected from the same soldiers who undergo TMA. The test will be performed at the USAEHA. Results of this assay will be described and analyzed jointly by USAEHA and WRAIR Division of Preventive Medicine.

Description of all BSI urine collection procedures is attached as Appendix E. Description of the **1HP** assay is **attached** as Appendix G.

Volatile Organic Compounds (VOC) Assay.

The pyrolysis of crude oil in a semichaotic milieu is thought to be largely incomplete and to yield a plethora of subfractions and compounds. Many of these are being assayed in the environment by the ongoing LJSAEHA ambient sampling. The VOC assay will **determine** accurate levels of a select battery of these compounds in the blood of a small group from the SP.

Peripheral blood will be collected from 32 soldiers and sent on wet ice to the Centers for Disease Control Center for Environmental Health and Injury Control laboratories for VOC assay. The senior researcher at that organization performing this task is David Ashley, Ph.D. These soldiers will **also** complete an additional questionnaire ("**VOC** questionnaire") regarding some specifics of their exposures prior to and during the surveillance time frame. These samples will be taken on the same schedule as the TMA samples.

Results of this assay will **be** described and **analyzed** jointly by the CDC,

USAEHA and WRAIR Division of **Preventive** Medicine.

Description of **all** blood collections involved in the BSI is attached as Appendix D. Description of the **VOC** assay protocol is attached in Appendix H.

Indirect Measures of Exposure

All SP members undergoing the following two tests will also **complete** a third questionnaire ("Genotoxics questionnaire") with questions regarding exposures to **activities**, foods, and compounds germane to the IWO assays.

Sister Chromatid Exchanges (SCE's).

SCE's are known to occur in human **lymphocytes** at both a background rate, and at accelerated rates under certain **stressors**. Among these **stressors** is exposure to numerous environmental toxins, such as PAH's. Thus SCE's are a nonspecific but very sensitive marker of exposure to numerous contaminants.

Assay of SCE frequencies in lymphocytes of the SP will be performed on 62 individuals. These will be performed predeployment and twice during deployment. SCE frequencies **will not** be assayed after return of the SP to Germany. This is **because** it is **well-documented** that induced increases in SCE frequency return to normal after an 18 day period. There is no need in this surveillance initiative to demonstrate that previously well-discussed phenomenon.

Assay of the SCE frequencies will be performed at **Microbiologicals, INC.** Rockville, MD, under the direction of Dr. David **Putman** and Dr. David **Jacobson-Kram**. Results of this assay will be described and analyzed under the direction of Dr. Melissa **McDiarmid**, Associate Professor, **Environmental** Health Sciences, the Johns Hopkins University School of Hygiene and Public Health. USAEHA and Dr. **McDiarmid** will collaborate- on using **environmental data** to **interpret** the SCE assay results.

Description of all blood collections involved in the BSI is attached in Appendix D. Description of the SCE assay protocol and discussion regarding sample size calculations are attached as Appendix I.

DNA-PAH Adduct assay.

Polycyclic Aromatic Hydrocarbons (PAH's) are known carcinogens, and are an expected product of the **uncontrolled** combustion of **crude** oil. When introduced into the human body, **PAH's** can form **covalent adducts** with deoxyribonucleic acid, or DNA. These can be measured by sensitive assay in peripheral blood lymphocytes. This **test** is also extremely specific, since the antibodies used in the assay are tailored for each specific **PAH** whose **adduct** is measured.

Assay of DNA-PAH **adducts** in DNA extracted from peripheral blood lymphocytes will be performed on the same 62 individuals undergoing SCE

assay. These will be performed **predeployment** and twice during deployment. DNA **adducts** will not be assayed after return of the SP to Germany.

This assays will be performed in two steps. First, DNA will be extracted from the peripheral lymphocytes under the direction of Dr. David **Jacobson-Kram**. The second phase will be the assay of **adducts** in these DNA extractions, under **the** direction of Dr. Miriam **Poirier**, National Cancer Institute, NIH, Bethesda, MD.

Results of **this** assay will be described and analyzed under the direction of Dr. Melissa **McDiarmid**, Associate Professor, **Environmental** Health Sciences, the Johns Hopkins University School of Hygiene and Public Health, along with Dr. **Jacobson-Kram** and Dr. **Poirier**. USAEHA will collaborate through Dr. **McDiarmid** regarding use of the environmental data for purposes of interpreting **the** DNA-PAH **adduct** assay results.

Description of all blood collections involved in the BSI is attached in Appendix D. Description of the DNA **adduct** assay protocol and discussion regarding sample size calculations are attached in Appendix J.

Cached Serum.

To provide a set of samples of biologic media which may be retained for additional assays, **sera** will be collected from the same soldiers who undergo TMA, and hard frozen for contingency use. This is essential because of the poorly-defined overall threat. In addition, the immune system may be an important target of inhaled **or** absorbed contaminants, and no work directly related to infectious disease has been incorporated. This step will allow a response to later information **that** may indicate such a need. These samples will be maintained at the **WRAIR** Division of Preventive **Medicine**. These samples will be taken on the same schedule as the TMA samples.

Description of all blood collections involved in the BSI is attached in Appendix D.

7-d. Follow up procedures.

No specific longitudinal follow-up procedures are identified at this time. The DOD Joint Working Group, Kuwait Oil Fires, will coordinate through the US Public Health Service on any plans for use of this project's data in future longitudinal work.

7-e. Disposition of data.

Data collected through the BSI will be centrally controlled and stored at the USAEHA, Occupational and Environmental Medicine Division. As previously stated, all records will be kept for a minimum of five years after the completion of all **reporting** from the BSI. Methods for destruction or erasure

procedures for data instruments with personal identifiers are described above.

7-f. Methods used for data collection.

Comparisons of **subsets** of measurements will **be utilized** for quality analysis and control. The kappa statistic will be **constructed** as a measure of comparability.

Data Analysis

This will be approached from two perspectives. First, the possibility of adverse health effects will be explored by analyzing measurements which directly reflect such effects, such as temporal trends in weekly sick call rates (MTF usage), emergence of new symptoms as self-reported on **questionnaires**, and changes in pulmonary function parameters (**FEV₁**, **FVC**). These will constitute outcomes, while biologic measurements (**TMA's**, **I-HP**, **SCE's**, **DNAA's & VOC's**), and subjective **exposure** indicators (diary comments, certain questionnaire items) will serve as independent **variables** and factors.

Second, the biologic measurements will themselves be treated as outcomes when they are correlated with concurrently obtained environmental measurements. Depending on the strength of such correlations, models will then be derived in which the **final** outcome is a **long-term** health effect such as carcinogenesis. This second perspective is **that** of the health risk assessment and will not **be** discussed in detail here.

Frequency data (e.g. health care access rates) and dichotomous measures (e.g. **reporting** vs. not **reporting** new symptoms, or **forming** vs. not forming DNA **adducts**) will be analyzed **across** time and among categorical variables (e.g. smoking vs. non-smoking) using chi-square tests for trend and for contingency tables. Fisher's exact test will be used for 2x2 tables. A multiple logistic regression model will be **applied** if needed to control for confounding.

Standardized **PFT** results (percent predicted **rates** & volumes) and the **quantitative** results of **TMA's**, **IHP**, **SCE's**, & **VOC's** will be explored for distribution and then subjected to analyses of variance across time points (pre-, during, and, if applicable, post-deployment) and in relation to possible confounding variables such as occupational category and pre-existing hypersusceptibility. Since the distribution of SCE frequency values is sometimes skewed, a square root transformation may be applied. **Non-parametric (Kruskal-Wallis)** tests will be **used** in addition to **ANOVA**, regardless of the normality of data. A repeated **measures** logistic regression model will be used to isolate the degree of change in biologic indicators attributable to environmental exposures.

8. Departure from plan for Individual patients

9. Incidents

Although **the** BSI does not entail any treatment modalities, and therefore no direct untoward effects of the BSI upon individuals can be

foreseeably anticipated. this project may identify early health effects or their markers. If such adverse health effects is revealed. or their presence reasonably suggested through work done in this project, appropriate actions will be taken.

These may include: notification of individuals in whom the presence of disease or adverse health effect is discovered, notification of the DOD Health Effects **Working** Group. Kuwait Oil Fires, for modifications of this plan, if any are indicated, and notification of command medical elements, if changes in troop disposition are suggested by information revealed.

10. Modification of plan

Modifications of this plan will be through LTC Deeter, USAEHA. All changes will also be communicated to ~~the~~ DOD Joint Working Group, Kuwait Oil Fires.

11. Examples of all forms to be used in the plan

See attached appendices.

12. Use of information and publications arising from the project

The USAEHA. LTC **Deeter**, will be the controlling agent for data collected as part of the **BSI**. All reporting will be through LTC Deeter or the Commander. USAEHA.

All publications arising from this project will have approval of the controlling MACOM. IAW AR **70-25, 70-14, 70-31, and 360-5.**

13. Special or unusual funding implications

The USAEHA will oversee the transfer of funds to agencies and concerns who sustain expenses or require payment related to execution of their respective parts of the BSI.

The **CEHC**, CDC will receive \$35,000 by MIPR ~~thru~~ the USAEHA for the processing of 4 x 32 samples for volatile organic chemical analysis.

The NCI. laboratory of Dr. Poirier. will receive **\$167.00/** sample for DNA adduct **ELISA** , or **\$30,000.00**

Microbiologicals, Inc. will perform the SCE frequency assay for a total price of \$38,300.00 for 3 x 62 samples.

The laboratory of Dr. **Jacobson-Kram** will receive funds for DNA extraction for DNA **adduct** assay.

Dr. Melissa McDiarmid will receive payment for consultation services.

Training in spirometry to **NIOSH** certification level will be purchased from Chesapeake Occupational Health, Baltimore, MD, at \$4,000.00 for 10 **persons**;

Other requirements of this nature will be approved through the PI. and coordinated by the Project Officer. Additional requirements will also be reported to the DOD Health Effects Working Group.

**14. Name and telephone number of the medical monitor,
when applicable:**

Not applicable

15. Human Use Committee (HUC) Review:

This plan will be reviewed as directed by the DOD Health Effects Working Group, Kuwait Oil Fires. That body will make all determinations regarding the applicability of regulations concerned with research, such as interpretations of minimal risk UP AR 70-25 or DODD 3216.2.

APPENDICES:

- Appendix A: Bibliography (for the BSI **plan**)
- Appendix B: **MTF** daily use log sheets 1 and 2. and **Questionnaires:** Predeployment. Interim. Genotoxics questionnaire, and VOC questionnaire
- Appendix C: Spirometry protocol/SOP
- Appendix D: Collection of peripheral blood, lymphocyte harvesting and sample preparation for **all** blood products
- Appendix E: **Collection** of urine for Trace metals and 1-OH pyrene assay
- Appendix F: Trace metals assay protocol
- Appendix G: 1-OH Pyrene assay protocol
- Appendix H: VOC analysis protocol
- Appendix I: **SCE** assay protocol
- Appendix J: DNA **adduct** assay protocol (two parts)
- Appendix K: Proposed agenda (timetable) for testing, results of **tests**, data entry. analysis, and **reporting**
- Appendix L: Areas of Responsibility
- Appendix M: Key personnel/PO C's
- Appendix N: Text of briefing given to volunteers and Informed consent form

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DAILY MEDICAL SURVEILLANCE SUMMARY

Instructions: For each day, (full 24 hour period) during the deployment, summarize the diagnostic categories of diseases seen on sick call and logged into the Medical **Surveillance** Report Form. In addition to the categories, tally the number of cases of diarrheal illness, upper **respiratory** illness, **urethritis** and malaria. Record also the number of patients in each category placed on quarters (#QTRS), admitted to the hospital (#ADMS), or returned to duty (#RTD). This form will be collected daily by a preventive medicine unit member.

Date: _____ Hours: _____ to _____

Name of MTF: _____ Total Population Served: _____

<u>DIAGNOSTIC CATEGORIES</u>	<u>#CASES</u>	<u>#RTD</u>	<u>#QTRS</u>	<u>#ADMS</u>
1. Febrile illness (FEV)	_____	_____	_____	_____
2. Gastrointestinal disease (GI)	_____	_____	_____	_____
3. Respiratory Disease (RES)	_____	_____	_____	_____
4. Dermatologic Illness (DER)	_____	_____	_____	_____
5. Genitourinary Illness (GU)	_____	_____	_____	_____
6. Ophthalmic Illness/Inj (EYE)	_____	_____	_____	_____
7. Heat or Cold Injury (H/C)	_____	_____	_____	_____
8. Orthopedic Injury (INJ)	_____	_____	_____	_____
9. Surgical Illness (SUR)	_____	_____	_____	_____
10. Psychiatric Illness (PSY)	_____	_____	_____	_____
11. Other Medical Illness (MED)	_____	_____	_____	_____
12. Dental Illness (DEN)	_____	_____	_____	_____
13. Miscellaneous visit (MIS)	_____	_____	_____	_____
14. Follow-up visit (FU)	_____	_____	_____	_____
<u>Special Diseases</u>				
Diarrheal Disease	_____	_____	_____	_____
Upper Respiratory Illness (URI)	_____	_____	_____	_____
Urethritis (sexual transmission)	_____	_____	_____	_____
Malaria	_____	_____	_____	_____

 (Reviewer's Signature)

MEDICAL SURVEILLANCE REPORT FORM

No.	MEDICAL TREATMENT FACILITY:			DATE OF REPORT:		TIME PERIOD OF THIS REPORT: hrs to hrs	ESTIMATE DIAGNOSTIC CATEGORY (see codes on reverse side)	SYMPTOMS IN RELATION TO GASTROINTESTINAL:					DISPOSITION (check which)					
	LAST NAME	RANK	LASTA	AGE	SEX			Day	Month	Fever >101	Vomit by	Diarr. alone	Check Symptoms Present: Daily, 1-3 times, 4-6 times, 7-10 times	Sore throat	Skin rash	Quarantined (hours)	Returned to duty	Admitted to hospital
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		

(33) How often do you experience hay fever or allergy symptoms?

<u>Never,</u> or less than twice a year	<u>Every</u> 7-3 months	<u>Every</u> 1-3 weeks	<u>Every</u> 1-3 days
---	-------------------------------	------------------------------	-----------------------------

(34) If you have had a job during the last 5 years where you were exposed to any of the substances listed below, please write down the kind of job and check off how severe the exposure was.

Exposure	Type of job	How bad was the exposure?:		
		mild	moderate	severe
Dusts	_____	_____	_____	_____
Gases or fumes	_____	_____	_____	_____
Smoke	_____	_____	_____	_____
Asbestos	_____	_____	_____	_____

If you have never worked around any of these please check here-->

(35) How often do you suffer each of the symptoms listed below?

	<u>Never,</u> or less than twice a year	<u>Every</u> 1-3 months	<u>Every</u> 1-3 weeks	<u>Every</u> 1-3 days
Nosebleeds	_____	_____	_____	_____
Palpitations	_____	_____	_____	_____
Indigestion or heartburn	_____	_____	_____	_____
Vomiting or nausea	_____	_____	_____	_____
Belly cramps or stomach pain	_____	_____	_____	_____

(36) How often do you experience indigestion or heartburn?

<u>Never.</u> or Less than twice a year	<u>Every</u> 1-3 months	<u>Every</u> 1-3 weeks	<u>Every</u> 1-3 days
---	-------------------------------	------------------------------	-----------------------------

SSN _____

(45) Have you felt depressed at any time during the last 6 months?

Yes No

(47) Has a doctor ever told you that you have nasal polyps?

Yes No

(48) Which of the following statements best describes how you feel about going to Kuwait? (Choose one)

- This will be the experience of a lifetime.
I am not complaining. It's part of being a soldier.
I am a little nervous about not knowing what to expect.
I don't want to leave my family or friends for that long.
I would rather not go.

(49) Check one or two of the following that most concern you about going in Kuwait.

- Being in an Arab country
The military threat
Unexploded ordnance
None of these things worries me
Lack of logistical support
Oust storms and sandstorms
Air pollution from the oil fires

(50) If you have any health problems or special concerns that were not addressed in this* questionnaire, please comment below.

Five horizontal lines for handwritten comments.

I have been briefed on the nature and purpose of the Kuwait deployment medical surveillance program and I have answered all of the questions in thii form to the best of my knowledge.

SSN Signature Date

**QUESTIONNAIRE TO ASSIST
INTERPRETATION OF BLOOD TESTS
FOR AIR POLLUTION EXPOSURE**

The information you enter on this form will be used to assess the preventive health needs of soldiers deploying to the Middle East, and will be kept confidential, in accordance with the Privacy Act of 1974.

Name / rank _____ SSN _____

(1) How many diagnostic X-rays (like a chest X-ray or a dental X-ray) have you received since arriving in Kuwait? _____

If none check here _____

(2) Please list all medications you are now taking and/or have taken since arriving in Kuwait.

(Include vitamins, aspirin, Tylenol, Motrin and oral contraceptives.)

How often do you now take it? (Check space):

Name of medication	Why taking	No longer taking	1-2 times / month	1-2 times / week	1 or more times / day
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Please answer #3 if you have smoked cigarettes since arriving in Kuwait.

- (3) a. Average no. smoked / day. _____ per day
(10 = 1 1/2 pack , 20 = 1 pack)
- b. Are you currently smoking cigarettes? _____ yes / no
- c. If stopped, how long ago? _____

Please answer #4 if you have smoked a cigar or pipe since arriving in Kuwait.

- (4) a. Average no. of times a day that you smoked a cigar or pipe. _____ per day
- b. Are you currently smoking a cigar or pipe? _____ yes / no
- c. If stopped, how long ago? _____

**Supplemental Questionnaire
Volatile Chemical Exposure**

In the last 3 days, (today, yesterday or the day before yesterday), have you either breathed or had on your skin any of the following:

	<u>Yes</u>	<u>No</u>	<u>Don't Know</u>
1. Diesel fuel or kerosene	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Gasoline	0	<input type="checkbox"/>	0
3. Paint Thinner, brush cleaner.....	0	0	<input type="checkbox"/>
4. Varnish, lacquer, wood stain, or wex paint.....	<input type="checkbox"/>	0	<input type="checkbox"/>
5. Bug or insect spray.....	0	<input type="checkbox"/>	0
6. Weed killer.....	<input type="checkbox"/>	<input type="checkbox"/>	0
7. Solid toilet bowl cleaners.....	<input type="checkbox"/>	0	<input type="checkbox"/>
8. Air freshner or room deodorizer	0	0	<input type="checkbox"/>
9. Moth balls or flakes	<input type="checkbox"/>	0	<input type="checkbox"/>
10. Fingernail polish or nail. polish remover.....	<input type="checkbox"/>	0	<input type="checkbox"/>
11. Dry cleaning fluid.....	<input type="checkbox"/>	<input type="checkbox"/>	3

12. *Have you cleaned your weapon with any cleaners or any other chemicals within the last three days?*

Yes 0 No 0 Don't Know

13. *Have you worked with, handled, or cur pressure treated wood within the last three days?*

Yes No Don't Know

14. *Please list any chemicals that you routinely work with in your normal job:*

15. *Please list any chemicals ^{that} you come into contact with as a result of any hobbies or off-duty activities:*

APPENDIX C

Standard Operating Procedure: Spirometry

Biologic Surveillance Initiative, Health Risk Assessment,
Kuwait Oil Fires

This SOP is taken from guidance in TB Med 509.

Applicability

This SOP will apply to all spirometry performed as part of the BSI.

Calibration

The evaluation of spirometer calibration is an equipment check which is essential prior to performing spirometry tests. Instrument inaccuracy is a source of error **which** is unacceptable, and it is easily detected and corrected. The potential for introducing spirometer error must be precluded by instituting the following series of equipment checks and procedures:

- a. Test the spirometers for accuracy daily or every 50 patients, whichever is more frequent. This is done by injecting 3.0 liters of room air from a calibrated syringe **into the spirometer**. To **be** accurate, the volume displayed on the spirometry tracing must equal the stated syringe volume ± 3 percent of the syringe volume (i.e., the recorded volume must fall in the range of 2.91 to 3.09 liters for a 3-liter calibrated volume). If a microprocessor is used with the spirometer, the same daily calibration requirements apply.
- b. Record the results of each equipment check in a **log**.
- c. Ensure that any inaccuracies identified during equipment checks **are** corrected prior to further use of the spirometer in patient testing.

Patient preparation

Prior to beginning the **spirometry** examination, the **spirometry** technician will explain the purpose of the test, identify potential indications for postponing spirometry, and properly position the patient for the forced **expiratory** maneuver.

- a. The procedure will **be explained** to the patient in simple

terms. The brief statement "I want to test how hard and fast you can breathe" may not be physiologically precise, but is usually the only explanation necessary.

b. Because the proper performance of spirometry is an **effort-dependent** phenomenon, testing will not be performed if the individual is acutely ill with upper respiratory tract complaints other than uncomplicated upper respiratory tract infections (colds) unaccompanied by profound systemic complaints. **Ci garettes** or aerosolized bronchodilators may transiently alter airway resistance, particularly in the smaller bronchi or bronchioles. Spiromerry will be postponed if the patient has used either of these in the past 2 to 3 hours. A recent heavy meal is also regarded as reason to postpone spirometry for approximately 1 hour. *Any deviations from this accepted standard of patient preparation will be indicated on the spiromerry tracing.*

c. The patient will be instructed to loosen tight clothing and to remove any dentures. The dentures may be left in place if, in the opinion of the **spirometry** technician, **their presence** will help the **patient** maintain a better **seal** around the mouthpiece. The individual may sit or stand, whichever is more comfortable and convenient. Most test subjects are comfortable sitting and, under normal circumstances, there is little difference **in** pulmonary function values obtained in either position. (The sole exception is in the case of a grossly obese individual where seated **test** results may be lower.) The chin should be elevated and the neck slightly extended, While the use of a **noseclip** is not explicitly required, it is highly recommended.

Test administration

a. Having been properly prepared **to** take the test, the patient is instructed on how to perform the forced expiratory maneuver. The spiromerry technician will ask the patient to take the deepest possible inspiration during a normal breathing pattern, close the mouth firmly around the outside of the mouthpiece, and without further hesitation, blow into the spirometer as hard, fast, and completely as possible. Before asking **the** individual to blow, the **spirometry** technician activates the recording function of the equipment in use and verifies its proper function. This should be done at least 1 second before the **subject** blows **into** the mouthpiece. While the patient is **blowing**, **the technician must actively coach the** subject until a smooth plateau occurs in the **tracing**. The forced expiratory **maneuver** may then be terminated.

b. This particular method of **eliciting** the forced expiratory maneuver is referred to as the *open circuit technique*. Most patients master this technique with minimal explanation and practice, consistently performing reproducible forced **expiratory** efforts. An occasional individual may have difficulties. Examples are failure to **maintain** an airtight seal around the mouthpiece, pursing of the lips as with a musical instrument, or obstruction of the mouthpiece with the tongue. These problems will be avoided by routinely demonstrating proper mouthpiece positioning to each patient. Make sure that the patient's chin remains elevated and neck slightly extended during the forced expiratory maneuver.

c. A valid spirometry examination must consist of three acceptable tracings in which the largest two vital capacities do not differ by more than 5 percent or 100 ml, whichever is greater. An acceptable **tracing** is one that is free of coughing, hesitant or false starts, inconsistent or variable effort, early termination of expiration, excessive variability, and baseline artifact. Tracings marred by coughing, hesitant starts, and inconsistent effort are illustrated in accompanying figures. The criteria for a valid spirometry examination are summarized in the accompanying **table**. Almost all subjects, when properly instructed and actively coached, can produce three acceptable tracings within five expiratory efforts. The spirometry technician should not elicit more than six expiratory maneuvers during one examination, since the patient's performance will not likely improve beyond this point.

Changes

Changes to this SOP will be through CPT Scott, action officer, or LTC Deerer, principal investigator.

SOURCE:

APPENDIX C -- Figures in support of text.

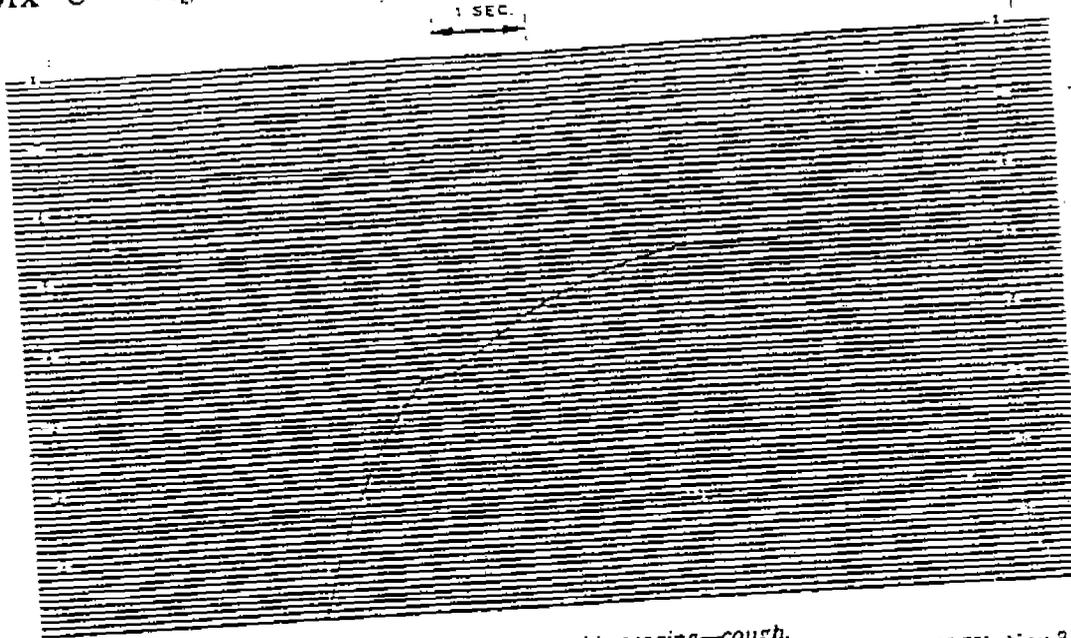


Figure 3-1. Unacceptable tracing—cough.
Source: Manual of Spirometry in Occupational Medicine, E.P. Horvath (editor), NIOSH, Nov 81.

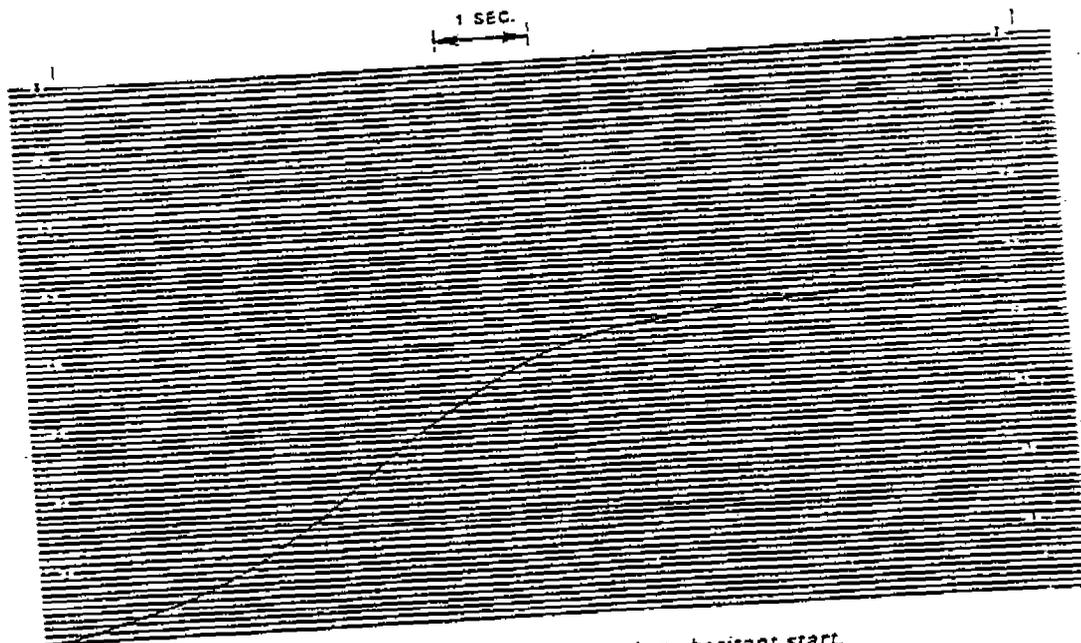


Figure 3-2. Unacceptable tracing—hesitant start.

APPENDIX C -- Figures in support of text.

SOURCE:

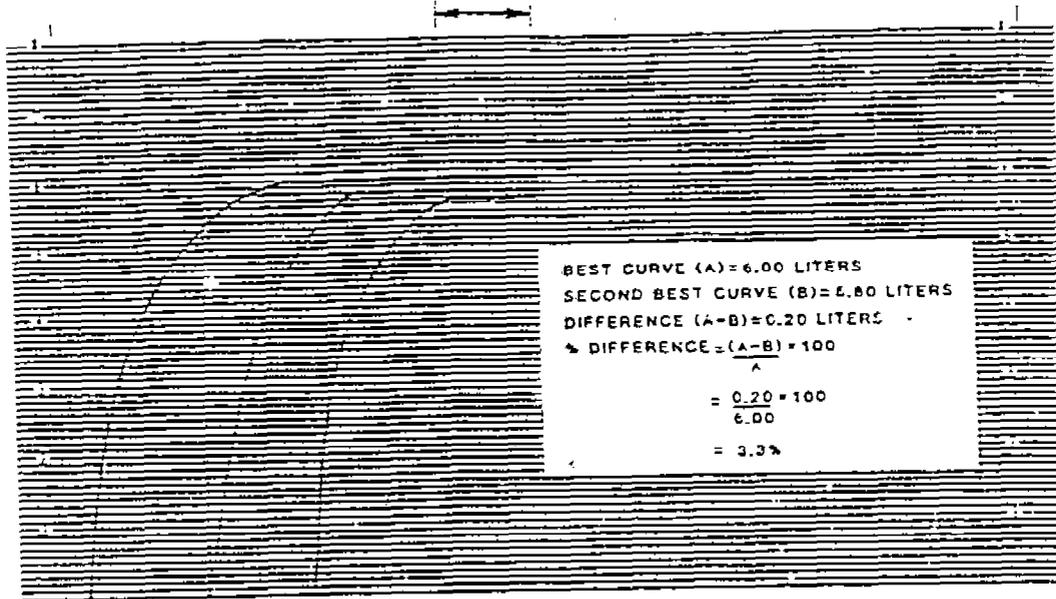


Figure 3-5. Valid spirometry examination—two best curves within 5 percent.

Table 3-1
Criteria for a valid spirometry examination

Three acceptable forced expiratory maneuvers free from—

Comment

Coughing

Hesitant or false starts.

Inconsistent or variable effort.

Early termination of expiration.

Excessive variability

Baseline artifact.

Active coaching is essential throughout the duration of the patient's effort.

End-of-test occurs when a plateau is noted in the tracing, with less than 25 mL volume change in 0.5 seconds

The two best FVC readings should not vary by more than 5 percent or 100 mL, whichever is greater.

The recording pen must begin tracing the subject's effort at the zero volume line.

APPENDIX D: Blood Collection and Fractionation
Plan for the Biologic Surveillance Initiative, Kuwait Oil Fires Health Risk
Assessment.

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DEPARTMENT OF THE ARMY
U.S. ARMY ENVIRONMENTAL HYGIENE AGENCY
EDGEWOOD AREA
ABERDEEN PROVING GROUND, MARYLAND 21010

HSBH-HO-R

29 JULY, 1991

STANDARD OPERATING PROCEDURE
FOR
COLLECTION OF PERIPHERAL BLOOD FOR BIOLOGIC SURVEILLANCE TEAM, KUWAIT OIL FIRES

1. PURPOSE: To establish guideline⁶ for the proper procedure⁶ to follow when drawing blood on individuals being **monitored** for **exposure** to the Kuwait oil fires.
2. SCOPE : This SOP applies to all military and civilian personnel who are exposed to smokes from the Kuwait oil fires and are under **surveillance** for said exposure.
3. REFERENCE:
 - a. AR 40-5, Preventive Medicine
 - b. FM 8-230 Medical Specialist
 - c. TB **MED** 503 The Industrial Hygiene **Program**
 - d. FM 8-273-1 Nursing **Skills** For Allied Health Services
4. RESPONSIBILITIES: This program **is** designed to enable the Surveillance Team staff to:
 - a. Perform medical surveillance for exposure to Kuwait oil fire smoke.
 - b. Properly label all samples and questionnaires for **surveillance**.
 - c. Draw all samples using proper sterile technique.
 - d. Handle and store all samples in a *manner* that is conducive with further testing and minimizes any deterioration of each sample.
5. GENERAL:
 - a. All vacutainers should be **labelled** prior to the drawing of any peripheral blood sample. This minimizes any **labelling** error⁶ that may occur and decreases handling of labels by the phlebotomist.
 - b. Before drawing any specimens, the phlebotomist will check **all** numbers of vacutainers and those present on the individual⁶ questionnaire to ensure that **mislabelling** has not occurred.
 - c. Phlebotomist shall **wear** proper eye protection and gloves,
 - d. Individual should be *seated* and **antecubital** *foasa* should be exposed on patient⁶ arm. **After** examining the patient⁶ arm for available access sites, the area should be cleaned with 70% isopropyl **alcohol**.
 - e. All vacutainers and vacutainer blood drawing sets (butterfly) should be readily available **before venipuncture** is performed.
 - f. A tourniquet should be applied proximal to the venipuncture site, then venipuncture should be performed and sample⁶ collected, then tourniquet

APPENDIX D: Blood Collection and Fractionation Page 2 of 4
Plan for the Biologic Surveillance Initiative, Kuwait Oil Fires Health Risk
Assessment.
removed, bandage applied.

g. Immediately after samples are collected, each vacutainer should be properly mixed to ensure that clotting- does not occur.

h. All samples should be placed together into a plastic bag to aid in further processing. These should then be placed in a cool environment (refrigerator or cooler with wet ice).

i. Samples should be kept on wet ice or refrigerated until further processing occurs. Any further processing and freezing should be accomplished as soon as possible-

APPENDIX D: Blood Collection and Fractionation
Plan for the Biologic Surveillance Initiative, Kuwait Oil Fires Health Risk
Assessment.

Page 3 of 4

DEPARTMENT OF THE ARMY
U.S. ARMY ENVIRONMENTAL HYGIENE AGENCY
EDGEWOOD AREA
ABERDEEN PROVING GROUND, MARYLAND 21010

HSHB-HO-R

29 JULY, 1991

STANDARD OPERATING PROCEDURE
FOR
COLLECTION OF BUFFY COAT (BLOOD FRACTIONATION PROTOCOL) FOR BIOLOGIC SURVEILLANCE
TEAM, KUWAIT OIL FIRES

1. PURPOSE: To establish guidelines for the proper procedure to follow when fractionating blood from individuals being monitored for exposure to the Kuwait oil fires.
2. SCOPE: This SOP applies to all military and civilian personnel who are exposed to smokes from the Kuwait oil fires and are under surveillance for said exposure.
3. REFERENCE:
 - a. AR 40-5, Preventive Medicine
 - b. FH 8-230 Medical Specialist
 - c. TB MED 503 The Industrial Hygiene Program
 - a. FM 8-273-1 Nursing Skills For Allied Health Services
 - e. Blood Fractionation Protocol from Johns Hopkins University
4. RESPONSIBILITIES: This program is designed to enable the Surveillance Team staff to:
 - a. Perform medical surveillance for exposure to Kuwait oil fire smoke.
 - b. Properly label all samples and questionnaires for surveillance.
 - c. Draw all samples using proper sterile technique.
 - d. Handle and store all samples in a manner that is conducive with further testing and minimizes any deterioration of each sample.
5. GENERAL:
 - a. Draw 40-45 mls of blood in three 15ml vacutainer tubes containing heparin (green tops)- Invert tubes occasionally until processing is accomplished.
 - b. Combine all three 15ml tubes into one 50ml centrifuge tube (Corning #25330).
 - c. Centrifuge at 1000g (2000rpm in counter top IEC clinical centrifuge) for 30 minutes using swing out buckets.
 - d. Blood should separate out into three layers; 1. serum/plasma, 2. Buffy coat 3. Packed RBCs.
 - e. Remove serum/plasma (top) layer to within a few mls of buffy coat at interface of plasma and red blood cells (RBCs), but do not disturb buffy coat. Save 13 mls of plasma/serum in 15 ml polypropylene screw top centrifuge tube (Corning #25319).

Plan for the Biologic Surveillance Initiative, Kuwait Oil Fires Health Risk Assessment.

f. Remove packed RBCs by carefully inserting a 14 gauge 4 inch pipetting needle (on 30ml syringe) through the edge of the buffy coat to the bottom of the tube. Slowly withdraw most of the RBCs, leaving 8 ml of blood in tube. This remaining 8 ml will contain the buffy coat, plasma and about 5mls of RBCs. Save 13mls of withdrawn RBCs in a 15ml screwtop polypropylene centrifuge tube (as above). Do no overfill tubes as they may burst with freezing.

g. You now should have two 15 ml tubeas (sera and RBCs) and one 50 ml tube (buffy coat) for each individual. Store frozen (-70C or dry ice, if not available -20C will do).

APPENDIX E : Urine Collection and Specimen Preparation Page 1 of 2
Plan for the Biologic Surveillance Initiative, Kuwait Oil Fires Health Risk
Assessment.

U.S. ARMY ENVIRONMENTAL HYGIENE AGENCY
EDGEWOOD AREA
ABERDEEN PROVING GROUND, MARYLAND 21010

HSHB-MO-R

29 JULY, 1991

STANDARD OPERATING PROCEDURE
FOR
COLLECTION OF URINE FOR BIOLOGIC SURVEILLANCE TEAM, KUWAIT OIL FIRES

1. PURPOSE: To establish guidelines for the proper procedures to follow when collecting urine from individuals being monitored for exposure to the Kuwait oil fires.

2. SCOPE: This SOP applies to all military and civilian personnel who are exposed to smokes from the Kuwait oil fires and are under surveillance for said exposure.

3. REFERENCE:

- a. AR 40-s. Preventive Medicine
- b. FM 6-230 Medical Specialist
- c. TB MED 503 The Industrial Hygiene Program
- d. FM 6-273-1 Nursing Skills For Allied Health Services

4. RESPONSIBILITIES: This program is designed to enable the Surveillance Team staff to:

- a. Perform medical surveillance for exposure to Kuwait oil fire smoke.
- b. Properly label all samples and questionnaires for surveillance.
- c. Obtain all samples using proper sterile technique.
- d. Handle and store all samples in a manner that is conducive with further testing and minimizes any deterioration of each sample.

5. GENERAL:

a. All specimen containers should be labelled prior to the collection of any urine sample. This minimizes any labelling errors that may occur and decreases handling of labels by the micturition technician.

b. Before obtaining any specimens, the micturition technician will check all numbers of specimen containers and those present on the individuals questionnaire to ensure that mislabelling has not occurred.

c. The micturition technician shall wear proper hand protection (gloves).

d. Individuals should be informed on proper technique to be used in order to obtain a contaminant free specimen (midstream clean catch specimen)- All individuals should be told of the importance of returning specimens as soon as possible with lids securely attached. Once this is accomplished, individuals should be directed to the nearest latrine or free standing facility.

e. Specimens should be placed in a cool environment (refrigerator or cooler with wet ice) as soon as they are returned by the individual-

f. Samples should be kept on wet ice or refrigerated until further

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Assessment.

processing occurs. Any further processing and freezing should be accomplished as soon as possible.

PROTOCOL FOR MEASUREMENT OF VOLATILE ORGANIC COMPOUNDS
IN HUMAN BLOOD USING PURGE/TRAP GAS CHROMATOGRAPHY
MASS SPECTROMETRY

Toxicology Branch
Division of Environmental Health Laboratory Sciences
Center for Environmental Health and Injury Control
Centers for Disease Control
Public Health Service
U.S. Department of Health and Human Services

introduction

This protocol describes methods developed and used at the Centers for Disease Control for the measurement of volatile organic compounds (VOCs) in human blood. This is a purge and trap (direct sparging with helium) gas chromatographic method using high resolution mass spectrometric detection in the full scan mode. The method is applicable to the determination of the 35 following compounds in 10 mL blood at approximately the detection limits given.

Analyte	Detection Limit (ppb)
1,1,1-Trichloroethane	0.04
1,1,2,2-Tetrachloroethane	0.01
1,1,2-Trichloroethane	0.02
1,1-Dichloroethane	0.01
1,1-Dichloroethene	0.02
1,2-Dichlorobenzene	0.03
1,2-Dichloroethane	0.01
1,2-Dichloropropane	0.01
1,3-Dichlorobenzene	0.04
1,4-Dichlorobenzene	0.03
2-Butanone	0.3
Acetone	200
Benzene	0.03
Bromodichloromethane	0.01
Bromoform	0.02
Carbon Disulfide	2
Carbon Tetrachloride	0.02
Chlorobenzene	0.01
Chloroform	0.02
cis-1,2-Dichloroethene	0.01
Dibromochloromethane	0.02
Dibromomethane	0.02
Ethylbenzene	0.02
Hexachloroethane	0.1

Hexane	2
m-/p-Xylene	0.02
Methylene chloride	0.05
o-Xylene	0.03
Styrene	0.01
Tetrachloroethene	0.02
Toluene	0.1
trans-1,2-Dichloroethene	0.02
Trichloroethene	0.005

Quantitation is achieved by isotope dilution in all cases by reference to commercially available labelled isotopes.

Summary

VOCs in whole blood are determined by heated purge and trap gas chromatography mass spectroscopy (GC/MS). Stable isotopically labelled analogs of the compounds of interest are added to 10 mL blood and this entire sample is injected into a specially designed sparging vessel which is already attached to the purging apparatus via air-tight seals. Prepurified helium gas is bubbled through the blood which is heated to approximately 35°C. This process removes volatile compounds from the sample into the gas stream. The purged volatile compounds pass into and are captured by a Tenax trap. Once the 15 minute purge cycle is complete, the Tenax trap is purged with dry helium gas for 6 minutes to remove absorbed water. The trap is then heated to 180°C for 4 minutes to desorb all volatile compounds. As the compounds are desorbed, they are trapped at the gas chromatograph injection port by a liquid nitrogen trap at -150°C. Following this period, the site is ballistically heated to 200°C injecting the compounds onto the DB-624 capillary column which is interfaced to the mass spectrometer. The mass spectrometer is operated in the full scan mode (40 - 200 amu) with one scan collected per second. Quantitation is accomplished from specific ion responses relative to those of the corresponding labelled analogs. The responses of analytes and analogs are corrected for contributions from each other through the use of an isotope dilution calculation. Final determinations are made based on six-point calibration curves and the concentrations are normalized according to sample weight.

Interferences

Compounds with similar chromatographic properties and characteristic mass spectral ions as the compounds of interest may interfere with the analysis. Care must be exercised in determining possible sources of these interferences and in some cases alternate ions should be selected to eliminate these. The use of high resolution mass spectrometry has proven to be of immense aid in this respect and has been shown to be absolutely necessary in certain cases.

Interferences which have their source in the measurement apparatus itself should be examined by determination of instrument blanks. For this purpose, a pure water sample remains attached to the measuring apparatus and is examined regularly to check for operational levels of instrument blanks. By leaving this sample attached to the measurement apparatus, exposure to airborne contaminants is eliminated and the level of volatiles in the sample are reduced to a

nondetectable level.

Glassware used for standards must be examined for sources of contamination. All glassware is heated in a vacuum oven at 150°C for at least 8 hours to remove adsorbed volatiles. The vacuum oven used contains an independent vacuum source since cross-contamination from other laboratory operations has been determined to be a major source of contamination of laboratory glassware. This glassware is cooled to room temperature before removal from the oven and sealed to diminish exposure to volatile compounds which are present in laboratory air.

The water used for dilution of standards and as water blanks is an extremely critical potential source of contamination. Numerous sources of water were examined to determine the most volatile-free water available. No commercial filtering or purification system was found which could consistently yield water at acceptable levels (< 20 ppt for most analytes). An acceptable source of water was discovered at a non-commercial site and all further studies make use of this source. Under some circumstances this source of water fails to yield acceptable levels of volatile organic compounds. In this case, the water is further purified to yield blank water with acceptable levels of VOCs. To prevent further contamination from the laboratory air, water samples are sealed in glass ampules. To provide consistency in measurement, all water samples used for a specific calibration curve have the same origin and are sealed at the same time. In all cases typical blank water levels are below the detection limits given above.

Since all commercially available vacutainers contain measureable levels of VOCs, the lots used to collect blood samples must be examined to determine levels of contamination present. This is accomplished by adding well characterized blank water to the vacutainers, allowing a reasonable exposure time to both the tube and the stopper and then characterizing these specimens for concentration of VOCs. In spite of these efforts, some compounds still have substantial contamination levels when compared to background levels of these compounds in blood. In particular, methyl chloride, dibromomethane, and carbon disulfide have large levels of interfering contamination in untreated vacutainers. Other analytes, including bromoform, chloroform, hexane, etc., also show contamination from vacutainers to a varying extent. Further efforts have been made to remove contamination from the vacutainers. This involves disassembly, heating in a vacuum oven, reassembly, restoration of vacuum, and sterilization. This process removes a substantial fraction of interfering analytes. All samples are now taken using these processed vacutainers.

Contamination by carryover must be examined over the entire range of analyte concentrations expected. The current purge and trap apparatus did not show any appreciable carryover for the analytes being measured over the standard concentration range presented here.

Safety

Many of the compounds used in this study are considered to be toxic or carcinogenic hazards. They should be treated as a potential health hazard in all cases. Always work under

a chemical fume hood when transferring these materials. Use a high draft fumehood and lower all the sashes because a number of these compounds are strong lachrymators and cause severe eye irritation at low concentrations. Wear appropriate gloves when handling these chemicals because all of them are readily absorbed through the skin.

Analyte concentrations in blood samples are at trace levels and therefore do not pose a substantial chemical hazard to personnel. Even though there is a minimal chemical hazard due to these samples, the microbiological hazard associated with whole blood samples necessitates the treatment of all blood samples as potential health hazards. Biosafety level 2 procedures should be followed when handling blood samples. These procedures include handling blood samples with protective gloves within a biological safety cabinet. After the sample has been analyzed it should be decontaminated with a chemical disinfectant and disposed as chemical waste. All glassware, etc. that contacts the blood samples should be treated as contaminated and autoclaved before disposal.

Standard Preparation

Positive displacement pipets are used for all transfer of liquids in the μL range. Transfers in the 5-30 μL range use a pipet with 0.1 μL increments. Transfers in the 51-100 μL range use a pipet with 0.2 μL increments. Transfers in the 101-250 μL range use a pipet with 1 μL increments. 25 mL class A sealable volumetric flasks are used to make all standards. Weights of neat compounds are determined on an analytical balance to the nearest 0.1 mg.

Standards are prepared with the following final concentrations (ppb):

Compound	# 1	# 2	# 3	# 4	# 5	# 6
1,1,1-Trichloroethane	0.05	0.1	0.5	1	5	10
1,1,2,2-Tetrachloroethane	0.005	0.01	0.03	0.1	0.5	1
1,1,2-Trichloroethane	0.007	0.014	0.07	0.14	0.7	1.4
1,1-Dichloroethane	0.005	0.01	0.05	0.1	0.5	1
1,1-Dichloroethene	0.01	0.02	0.1	0.2	1	2
1,2-Dichlorobenzene	0.005	0.01	0.05	0.1	0.5	1
1,2-Dichloroethane	0.004	0.009	0.04	0.09	0.4	0.9
1,2-Dichloropropane	0.005	0.01	0.05	0.1	0.5	1
1,3-Dichlorobenzene	0.004	0.009	0.04	0.09	0.4	0.9
1,4-Dichlorobenzene	0.04	0.08	0.41	0.8	4	8
2-Butanone	0.06	0.12	1.2	2.5	12	25
Acetone	200	400	900	1800	3800	6000
Benzene	0.01	0.02	0.1	0.2	1.2	2
Bromodichloromethane	0.005	0.01	0.05	0.1	0.5	1
Bromoform	0.02	0.04	0.20	0.4	2	4
Carbon Disulfide	2.4	4.8	20	40	80	120
Carbon Tetrachloride	0.004	0.009	0.04	0.09	0.4	0.9

Chlorobenzene	0.004	0.009	0.04	0.09	0.4	0.9
Chloroform	0.009	0.018	0.09	0.18	0.9	1.8
cis-1,2-Dichloroethene	0.009	0.018	0.09	0.18	0.9	1.8
Dibromochloromethane	0.004	0.009	0.04	0.09	0.4	0.9
Dibromomethane	0.02	0.04	0.2	0.4	2	4
Ethylbenzene	0.01	0.02	0.1	0.2	1	2
Hexachloroethane	0.006	0.012	0.06	0.12	0.6	1.2
Hexane	4	8	32	64	130	190
m-Xylene	0.01	0.02	0.20	0.41	2.1	4.1
Methylene chloride	0.02	0.04	0.42	0.83	4.2	8.3
o-Xylene	0.025	0.05	0.25	0.5	2.5	5
p-Xylene	0.01	0.02	0.20	0.41	2.1	4.1
Styrene	0.008	0.017	0.08	0.17	0.8	1.7
Teaachloroethene	0.02	0.04	0.2	0.4	2	4
Toluene	0.01	0.02	0.2	0.4	2	4
trans-1,2-Dichloroethene	0.01	0.02	0.1	0.2	1	2
Trichloroethene	0.004	0.009	0.04	0.09	0.4	0.9

Native analyte standards are made by successive dilution in methanol from the neat compounds. Because of variation in the volatility of these compounds, the use of concentrated stock solutions for long term storage is unacceptable. The intermediate stock solutions are prepared fresh from the neat compounds every three months. These solutions are scaled in glass vials and placed in a -60°C freezer until used. This has proven to be a successful method of preserving standard integrity. On the day of use, the standard is prepared by dilution of the appropriate volume of these intermediate stock solutions into 25 mL of contaminant-free water.

Labelled analog solutions are prepared to achieve the following approximate final concentrations (ppb):

1,1,1-Trichloroethane-D ₃	1
1,1,2,2-Tetrachloroethane-D ₂	0.1
1,1,2-Trichloroethane-D ₃	0.1
1,1-Dichloroethane-D ₃	0.1
1,1-Dichloroethene-D ₂	0.2
1,2-Dichlorobenzene-D ₄	0.25
1,2-Dichloroethane-D ₂	0.2
1,2-Dichloroethene-D ₂ (mix)	0.2
1,2-Dichloropropane-D ₆	0.2
1,4-Dichlorobenzene-D ₄	2
2-Butanone-D ₃	a
Acetone- ¹³ C ₃	25
Benzene- ¹³ C ₆	0.2
Bromodichloromethane- ¹³ C	0.1
Bromoform- ¹³ C	0.5

APPENDIX H: Volatile **Organics** in Serum Assay Protocol

Carbon disulfide- ¹³ C	5
Carbon tetrachloride- ¹³ C	0.1
Chlorobenzene-D ₅	0.2
Chloroform- ¹³ C	0.1
Dibromochloromethane- ¹³ C	0.1
Dibromomethane- ¹³ C	0.1
Ethylbenzene-D ₁₀	0.4
Hexachloroethane- I - ¹³ C	0.5
Hexane-D ₁₂	4
Methylene chloride- ¹³ C	0.5
o-Xylene- ¹³ C ₂	0.2
p-Xylene-D ₁₀	0.7
Styrene-D ₈	0.2
Tetrachloroethene- ¹³ C	0.1
Toluene-D ₈	0.2
Trichloroethene- ¹³ C	0.05

Labelled analog solutions are made by successive dilution in methanol from the neat compounds. Concentrated stock solutions are stored in sealed ampules at -60°C. Because of the major expense in acquiring these label analogs further dilutions are made from these concentrated stock solutions. Intermediate stock solutions of these analogs are prepared fresh every three months. These solutions are sealed in glass ampules and stored at -50°C until used. On the day of use, the analog solution is prepared by dilution of the appropriate volume of intermediate stock solution into 25 mL of methanol. 20 uL of this analog solution is added to each blank, standard, whole blood, or quality control sample before injection into the purging apparatus.

Sample Collection

Previous studies of VOCs indicate that their half-life in human blood is relatively short. In most cases, values between 6 and 24 hours are considered to be the best estimates for these half-lives. Because VOCs do not reside long in the body, special sample collection considerations are necessary. Except in cases of extremely high exposure, sampling of blood after as much as 3 days after removal from exposure will not indicate abnormal levels in the blood. Of course the length of time after exposure for which useful samples can still be obtained will vary with the level of exposure. It is therefore suggested that samples be obtained either before removal from exposure or as quickly after this time as possible. This will require preparation well before assessment of environmental levels. Thus, it is highly desirable that protocols, release forms, and sample collection materials be ready and on hand when assessment begins. This will enable the collection of blood samples before the VOCs are excreted from the body.

Samples are collected by venipuncture using grey top vacutainers which contain potassium oxalate / sodium fluoride as anticoagulant. Two 10 mL tubes are collected from each individual, the second tube being used for examination of reproducibility and sample stability.

Within 15 minutes the samples are placed on wet ice or stored at refrigerator temperatures. The samples should not be frozen or allowed to stand for an extended **length** of time at room temperature.

Samples should be shipped via next day **carrier** in insulated containers along with enough ice packs so that the **temperature** can be maintained during the shipping process. Shipments should not be made which will arrive on weekends or federal **holidays**. All shipments **are made** to

Centers for Disease Control
Bldg 17, Room 1814, F17
4770 Buford Highway
Chamblee, Georgia 30341
Attn: Dr. David **Ashley**

Preliminary experiments have indicated that the concentration of some **volatile analytes** changes **over** sample storage time. Therefore, the samples should be shipped within 1 - 2 days of collection so that they **can** be analyzed within 2 - 3 weeks of collection.

Sample Preparation

Before sample introduction the **purging** vessels are thoroughly **cleaned** with methanol, **heated overnight**, a small portion of **antifoam** agent added, and the vessels heated and purged through **one** regular **purge** and **trap** cycle with no sample present- This assures the removal of any remaining contamination **from** the vessel and **antifoam** agent.

10 **mL** samples are **extracted** into a **gas-tight** syringe which has been thoroughly washed with methanol and '**contaminant-free**' water. **The** syringe is **weighed** to the **nearest** 0.01 **g** both before and after extraction of the sample. These numbers are subtracted to determine the sample weight. To the syringe is added 20 **uL** of the analog solution. The syringe is attached to the purging apparatus via a **luerlock** fitting, the valve is opened, the sample is injected into the purging vessel, and the valve is closed before removal of **the syringe**. **A typical daily** work load consists of an **instrument blank**, a water blank, an **analytical** standard, 3 **unknowns**, and a quality control sample.

Instrumentation

The **purge** and trap apparatus consists of a **Tekmar LSC 2000** purge and **trap** concentrator with an attached **ALS 2016** automated sampler- **This system** allows up to 16 samples to be loaded for processing **at** one time. Because of **lack** of communication between the sampler and the mass **spectrometer** data **system**, the method **requires operator** attention **at** particular steps in the analysis routine. **Helium** flow **rate** is **maintained at** 30 **ml/min** at 20 psi. This flow rate is critical since too large a flow will cause column breakthrough and reduce sensitivity **to low** boiling compounds. For sample analysis **the** following steps are programmed into **the** purge and

trap concentrator.

<u>Step</u>	<u>Time</u>	<u>Temperature</u>
Preheat	3.00 min.	30°C
Purge	15.00 min.	30°C
Dry Purge	6.00 min.	30°C
Cap Cooldown		-150°C
Desorb Preheat		175°C
Desorb	4.00 min.	180°C
Inject	0.75 min.	200°C
Bake	36.00 min.	225°C

Analyte separation is carried out on a Hewlett-Packard model 5890 gas chromatograph specifically modified to allow channeling of effluent through a heated interface into the mass spectrometer. The chromatograph is equipped with a J & W 30rn DB-624 column with 1.8 μ m film thickness. The gas chromatograph uses the following temperature program:

<u>Temperature</u>	<u>Hold Time</u>	<u>Rate (°/min.)</u>	<u>Ramp Time</u>
0°C	1.5 min.	12.0	2.5 min.
30°C	2.0 min.	8.0	20.0 min.
190°C	10.0 min.		

The mass spectrometer is a VG Analytical 70E high resolution mass spectrometer operating at 300.0 resolving power. Instrument tuning and resolution must be checked before each experimental run. Masses are calibrated versus perfluorokerosene. The instrument is operated in full scan mode (40 - 200 amu).

The following masses are used as quantitation ions:

Analyte	Quantitation Ion	Analog	Quantitation Ion
1,1,1-Trichloroethane	99.9800	1,1,1-Trichloroethane-D ₃	96.4612
1,1,2,2-Tetrachloroethane	82.9455	1,1,2,2-Tetrachloroethane-D ₂	83.9518
1,1,2-Trichloroethane	96.9612	1,1,2-Trichloroethane-D ₃	99.9500
1,1-Dichloroethane	63.0001	1,1-Dichloroethane-D ₃	66.0189
1,1-Dichloroethene	95.9534	1,1-Dichloroethene-D ₂	64.9941
1,2-Dichlorobenzene	145.9690	1,2-Dichlorobenzene-D ₂	151.9912
1,2-Dichloroethane	61.9923	1,2-Dichloroethane-D ₄	67.0060
1,2-Dichloropropane	63.0002	1,2-Dichloropropane-D ₆	67.0253
1,3-Dichlorobenzene	145.9690	1,4-Dichlorobenzene-D ₄	151.9912
1,4-Dichlorobenzene	145.9690	1,4-Dichlorobenzene-D ₄	151.9912
2-Butanone	72.0575	2-Butanone-D ₃	75.0764
Acetone	59.0452	Acetone- ¹³ C ₃	61.0519
	60.0486		
Benzene	78.0470	Benzene-?,	84.0671

	77.0391		
Bromodichloromethane	82.9455	Bromoform- ¹³ C	173.8458
Bromoform.	172.8425	Bromoform- ¹³ C	173.8458
Carbon Disulfide	77.9399	Carbon disulfide- ¹³ C	7s.9433
	75.9441		
	79.9357		
Carbon Tetrachloride	116.9066	Carbon tetrachloride- ¹³ C	117.9099
Chlorobenzene	112.0080	Chlorobenzene-D ₃	117.0394
Chloroform	82.9455	Chloroform- ¹³ C	83.9489
cis-1,2-Dichloroethene	95.9534	cis-1,2-Dichloroethene-D ₂	64.9941
Dibromochloromethane	125.8923	Chlorodibromomethane- ¹³ C	129.8958
Dibromomethane	92.9339	Bromoform- ¹⁵ C	173.8453
Ethylbenzene	106.0783	Ethylbenzene-D ₂	116.1410
Hexachloroethane	165.8725	Hexachloroethane-1- ¹³ C	166.8758
Hexane	86.1096	Hexane-D ₁₄	100.1974
	87.1129		
m-/p-Xylene	106.0783	p-Xylene-D ₁₀	116.1410
Methylene chloride	s3.9534	Methylene chloride-?	84.9567
o-Xylene	106.0783	o-Xylene- ¹³ C ₂	116.1410
Styrene	104.0626	Styrene-D ₈	112.1128
Tetrachloroethene	165.8725	Tetrachloroethene- ¹³ C	166.8758
Toluene	91.054s	Toluene-D ₈	98.0987
	65.0391		
trans-1,2-Dichloroethene	95.9534	trans-1,2-Dichloroethene-D ₂	64.9941
Trichloroethene	129.9144	Trichloroethene- ¹⁵ C	130.9177

In some cases, two or more masses are indicated.. These allow a wider dynamic range in measurement for certain analytes.

Data Analysis

Data are processed. automatically by a chromatogram generation, peak detection and quantitation routine specifically designed for this application. This routine provides for hard copy output of all chromatograms with peak detection indicated, full scan spectra at all detected peak maxima, and highly expanded mass spectra around the ions of interest. All peaks which are automatically detected are individually checked for proper integration. AU spectra are checked for appearance of interferences which may occur in the quantitation windows. Correction is made for the o-xylene contribution to the styrene signal.

Isotope Dilution Calculations

Quantitation is achieved by determination of relative response factors between native analytes and labelled analogs added to the sample being examined. The analog levels are kept constant and calibration curves of the relative response between analyte and analog are plotted

for standards at five different concentrations which cover the range of interest. In most cases, native analytes have some response at the mass used for determination of contribution for the labelled isotope. Likewise, the labelled isotope often contributes some response at the mass being used for analyte quantitation. In these cases corrections must be made for the contribution of labelled analyte to the native ion and vice versa. In order to properly determine relative response factors between the analyte and analog, these effects must be taken into account. This is the basis for the use of more complex isotope dilution calculations.

The following ratios must be determined for correct use of these calculations.

For the native analytes,

$$R_x = \frac{\text{area of quantitation ion of the analyte at analyte retention time}}{\text{area of the analyte contribution to the quantitation ion of the labelled analog at analyte retention time}}$$

For the labelled analogs,

$$R_y = \frac{\text{area of labelled analog contribution to the quantitation ion of the analyte at analog retention time}}{\text{area of the quantitation ion of the labelled analog at analog retention time}}$$

These ratios are a measure of the degree to which the native analytes contribute labelled analog signal and vice versa. If measured correctly, R_y will also account for the presence of native analyte present in the labelled spiking solution. These ratios are measured by adding enough of the solutions of interest to overwhelm any contribution from contamination.

If no area is detected in the denominator of the R_x calculation, R_x should be set to a number substantially larger than 1. In this protocol 1000000 was chosen. If no area is detected in the numerator of the R_y calculation, R_y should be set to a number substantially smaller than 1. In this protocol 0.000001 was chosen. This will allow use of the same calculation in cases in which there is no contribution of analog to analyte signal or analog to analyte signal.

The ratio of the analyte signal to the analog signal must then be determined for each sample, standard, blank or QC material. This is given as

$$R_m = \frac{\text{area of the quantitation ion of the analyte at analyte retention time}}{\text{area of the quantitation ion of the labelled analog at analog retention time}}$$

The relative response is calculated from the above ratios as

$$RR = \frac{(R_y - R_m)(R_x + 1)}{R_x}$$

Procedure for Sister Chromatid Exchange Analysis

Peripheral blood lymphocytes were cultured in RPMI 1640 (GIBCO) medium supplemented with 15% fetal bovine serum, 1% penicillin-streptomycin, 1% phytohemagglutinin (Burroughs-Wellcome) and 10 $\mu\text{g}/\text{ml}$ 5-bromo-2'-deoxyuridine (BrdU)/ml (complete medium). Cultures were established by adding 0.6 ml of whole blood to 15 ml centrifuge tubes containing 9.4 ml complete medium. The cultures were then incubated at $37 \pm 1^\circ\text{C}$ with 5% CO_2 in air for 68-70 hours. The treatment tubes were identified by sample ID number. Two hours prior to harvest, Colcemid was added to each culture at a final concentration of 0.1 $\mu\text{g}/\text{ml}$. After harvest by centrifugation, the cells were subjected to hypotonic swelling in 0.075 M KCl and fixed in three changes of Carnoy's fixative (methanol:glacial acetic acid, 3:1, v/v) and then stored overnight or longer at approximately $0-6^\circ\text{C}$. The cells were suspended in a small volume of fixative and applied dropwise onto precleaned, wet slides. The slides were stained with Hoechst 33258 (5 $\mu\text{g}/\text{ml}$) for approximately 10 minutes, mounted in phosphate buffer, exposed to a black light lamp with 15 watt tubes for approximately 4-5 minutes and then rinsed and countersained with 5% Giemsa solution at pH 6.6 for 10 minutes.

Cytogenetic evaluations were performed without observer knowledge of the cell source. Whenever possible, a total of 25 well-spread and well-stained second-division metaphases were evaluated per culture.

APPENDIX J: DNA Extractions Protocol

Procedure for Extracting DNA From Human Nucleated Cells

Buffy coats of nucleated cells obtained from anticoagulated blood will be resuspended in 50 ml polypropylene centrifuge tubes with 15 ml of nuclei lysis buffer (10mM Tris-HCl, 400 mM NaCl and 2 mM Na₂EDTA, pH 82). The cell lysates will be digested overnight at 37°C with 1.0 ml of 10% SDS and 25 ml of a protease K solution (1 mg protease K in 1% SDS and 2 mM Na₂EDTA).

After digestion, 5 ml of saturated NaCl (approximately 6 M) will be added to each tube, the tube vigorously shaken for about 15 seconds, followed by centrifugation at 2500 rpm for 15 minutes. The precipitated protein pellet will be left at the bottom of the tube and the supernatant containing the DNA transferred to another 50 ml polypropylene tube. Exactly 2 volumes of room temperature absolute ethanol will be added to the tube and the tube inverted several time until the DNA precipitates.

The precipitated DNA will be removed with a tie-polished glass Pasteur pipet or micropipet tip to a 15 ml polypropylene centrifuge tube containing 0.5 to 1 ml TE buffer (10 mM Tris-HCl, 0.2 mM Na₂EDTA, pH 7.5). The DNA will be allowed to dissolve at least 2 hours at 37°C before quantitating.

An equal volume of chloroform will be added to each tube containing the DNA in TE buffer. The tubes will be rocked by hand until an emulsion is formed. The emulsion will be centrifuged at 1600 x g at room temperature for at least 3 minutes. Using a transfer pipet, the upper aqueous phase will be transferred to a fresh polypropylene tube and the volume transferred estimated. The interface and lower organic phase will be discarded.

The concentration of monovalent cations will be adjusted either by dilution with TE buffer (pH 8.0) if the DNA solution contained high salt concentration or by addition of 5 N NaCl solution to achieve a final concentration of 0.1 M.

Exactly 2 volumes of ice-cold absolute ethanol will be added to the tube and the tube inverted several time until the DNA precipitates. The tube will be stored at -20°C for 30 to 60 minutes to facilitate DNA precipitation if needed. The sample will be centrifuged at 12000 x g at 0°C for at least 10 minutes. The supernatant will be discarded. The tube will be inverted on adsorbent paper and remaining fluid aspirated in capillary tubes or micropipet tips.

The pelleted DNA will be resuspended in TE buffer such that initially the concentration will be higher than 500 µg/ml. The DNA concentration will be determined by W absorption at 260 nm. The DNA concentration will be adjusted to 500 µg/ml by addition of additional TE buffer. DNA samples will be stored at 4°C.

APPENDIX K: PROPOSED AGENDA (TIMETABLE)

Plan for the Biologic Surveillance Initiative, Kuwait Oil Fires Health Risk Assessment.

DATE	DATA COLLECTION	LAB and DATA ANALYSIS	REPORTING
	PHASE I - Predeployment data collection		
15-May-91	Initial Planning meetings and Design - 1 week	Computations retained Collaborators recruited	
2-Jun-91	Team Travels to Germany for Predeployment data collection		
7-Jun-91	Genotoxic samples shipped to CONUS Lab Accession begins for SCE assay samples		
9-Jun-91	Team returns from Germany Lab accession begins for VOC assay, metals, other	Accession begins SCEs, Metals, VOC's	
	PHASE II - Interim collection 1		
6-Aug-91	Team departs CONUS for KTO		
10-Aug-91	Team performs collections in Kuwait City		
12-Aug-91	Genotoxic/VOC samples flown to CONUS		
17-Aug-91	Team returns to CONUS	DNA extractions begin	
Sep-91		DATA entry begins for questionnaires, spirometry	
	PHASE III - Interim collection 2		
1-Oct-91	Team departs CONUS for KTO		
	Team performs collections in Kuwait City	First metals finished	
7-Oct-91	Genotoxic/VOC samples flown to CONUS		
12-Oct-91	Team returns to CONUS	First SCE set completed Last SCE set accessed Data entry continues	Preliminary 1st SCE results Prelim 1st VOC results Prelim 1st metals results
Nov-91			
	PHASE III - Post-Deployment Data Collection		
1-Dec-91	Team Travels to Germany for Predeployment Data collection		
4-Dec-91	Team performs collections in Germany		
5-Dec-91	VOC samples flown to CONUS		
4-Dec-91	IH sampling performed in 11 ACR area		
18-Dec-91	Team returns to CONUS		
31-Jan-92		Metals, VOC's finished Last SCE set finished All DNA extracted; Start ELISA for adducts Data analyses begin	
28-Feb-92			Last SCE Results
28-Mar-92		ELISA finished for DNA Adducts	
May-92		Data entry finishes	Preliminary BSI components report
Jun-92		Data analyses continue	Preliminary overall BSI report
Sep-92		Data analyses finish	
Nov-92			Final reports integrating BSI with NRA
Jun-93			Possible literature publication window

Plan for the Biologic Surveillance Initiative, Kuwait Oil Fires Health Risk Assessment.

1. The principal Investigator (PI):
 - a. will oversee planning and integration at all stages of the BSI
 - b. will supervise and execute reporting of the BSI results
 - c. will establish collaborative relationships and be responsible for recruitment of collaborating investigators.
 - d. will effect communication among collaborative parties and among elements of the USAEHA.
 - e. will take responsibility for safeguarding and transmitting data, identifiers, and results as appropriate to the several tasks in the BSI.
2. The DOD Health Effects Working Group, Kuwait Oil Fires will:
 - a. provide continuing guidance for this initiative.
 - b. appoint a new PI in the event that the PI now acting cannot complete the project.
 - c. oversee the approval process for this plan, and for BSI results and publications.
3. Associate Investigators
 - a. Dr. David Ashley, CDC will conduct VOC assay. He will oversee quality and technical aspects of that assay. He will report to the PI on results. He will collaborate on analyses and interpretation of the data from this assay, and on integration of the DNA adduct assay with environmental data from the HRA.
 - b. CPT David Gustavison will be the Occupational Medicine Resident assigned to this initiative at the USAEHA. He will function at the direction of the Residency Program Director, working with the Project Officer (PO), CPT Scott.
 - c. Dr. Jack Heller, Health Risk Assessment Branch (HRAB), USAEHA, will oversee integration of the BSI with the Kuwait Oil Fires Health Risk Assessment (HRA). He will provide guidance to the PO regarding any changes or adaptations which may be identified as needs. He will coordinate the flow of environmental data from the HRA for integration with the BSI.
 - d. Dr. David Jacobson-Gram, Associate Professor of Oncology, the Johns Hopkins Medical Institutions (JHMI), and Microbiologicals, Incorporated (MI), Rockville, MD, will oversee production of DNA extracts, and on interpretation of DNA adduct data integrated with environmental data from the HRA. He will coordinate reporting with Dr. McDiarmid.

Plan for the Biologic Surveillance Initiative, Kuwait Oil Fires Health Risk Assessment.

e. Dr. Victor F. Kalasinsky, Armed Forces Institute of Pathology (AFIP) will conduct trace metals analyses. He **will oversee** quality and **technical** aspects of **that** assay. He will report to the PI on **results**. He will collaborate on analyses and interpretation of the data from this assay, and on integration of **the** DNA **adduct** assay with environmental data from the HRA.

f. MAJ Richard M. Lachiver, USAEHA will continue to collaborate on planning, data collection, **data** entry, data analyses, and integration of the overall BSI as his duties and position permit.

g. Dr. Melissa A. McDiarmid, The Johns Hopkins University School of Hygiene and Public Health, will **serve** as principal consultant for genotoxics assay and evaluations. She will track **execution** of **these** assays through the appropriate other associate investigators. She will oversee the **reporting** of SCE and DNA **adduct** assays to the PI. She will manage data **handling** for these assays. **With the PI**, she will effect data analyses for these assays. She will moderate communications among all the associate **investigators** conducting the DNA **adduct** and SCE **frequency** assays.

h. MAJ Bruno Petruccelli, WRAIR, will manage data handling **for** the overall BSI. He will conduct database construction and manipulation. He **will** be responsible for description, analysis, and interpretation of the results of this initiative. He will work with the PO on needs for these components, and **report to the PI** on progress. He will, with the PI, prepare reports **on** the overall BSI results.

i. Dr. Miriam Poirier, National Cancer Institute (NCI) **will** conduct ELISA for DNA **adducts**. She will oversee quality and technical aspects of **that** assay. She will **coordinate** reporting **with** Dr. McDiarmid. She will collaborate on analyses and **interpretation** of the data from this assay, and on **integration** of the DNA **adduct** assay with **environmental** data from the HRA.

j. CPT Brian Scott, USAEHA, **will serve** as Project Officer for the BSI. He will effect the measures directed by the PI and the DOD Health Effects Working **Group**. He will:

1. prepare the BSI plan
2. effect communications with all OCONUS parties for execution of the data collection phases of this initiative.
3. **report as** needed **to** the PI and **to the** DOD Health Effects Working Group.
4. serve as Physician POC for the **HRA** management through **the** HRAB and **Dr. Heller**. In this capacity, he will advise the HRAB on modification of the exposure **factors** used in modeling. He will continue to advise **the HRA team** on any **new developments**.
5. accomplish necessary fund manipulations and **contracting** through RMD, USAEHA.

Plan for the Biologic Surveillance Initiative, Kuwait Oil Fires Health Risk Assessment.

6. execute identification of data **collection** team members through the PI. He will accomplish assembly, POR, training, movement, deployment, oversight, and mission **execution of the data collection teams in** and to all OCONUS locations (Kuwait and Germany) for **Phases II-IV of the BSI**. He will serve as OIC of the data **collection** missions for phases II-IV.

7. **serve** as POC for all associate investigators. He will maintain communications channels, and **expedite** adaptations of plans and **processes** as needed.

3. **Changes** to this description of responsibilities will be through the PI, LTC David Deeter, USAEHA.

Plan for the **Biologic Surveillance Initiative, Kuwait Oil Fires Health Risk Assessment.**

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APPENDIX M : Key Personnel and Points of Contact Page 2 of 2

Plan for the Biologic Surveillance Initiative, Kuwait Oil Fires Health Risk Assessment.

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HEALTH EFFECTS OF THE OIL FIRES IN KUWAIT

Surveillance of U.S. Army Personnel

The U.S. Army Environmental Hygiene Agency (AEHA), at the request of the Surgeon General of the Army, has been monitoring the air quality in Kuwait to assess any health risk to soldiers and civilians living and operating in the region. This monitoring was prompted by the smoke arising from burning oil wells. Despite the visible intensity of this smoke, the AEHA--working together with the U.S. Environmental Protection Agency, the Centers for Disease Control, and other federal and private organizations--has determined that the concentration of toxic gases and nuisance particles from a wide range of locations around the fires is very low. Much of the air that has been monitored was right inside the smoke plume itself. While persons with asthma or chronic lung disease may experience a temporary worsening of their symptoms, no harmful health effects are expected to occur among U.S. troops working around the oil fires.

At the same time that REHA is monitoring air quality, it is tasked to make certain that any possible effects on soldiers will not go unnoticed, so that actions can be taken to avoid further risk. To do this, preventive medicine officers must conduct special tests on a representative sample of persons deploying to Kuwait, and compare the results with tests done once during and once after their stay in the region. Again no significant changes are expected, but it is important to provide the best possible health care to U.S. soldiers.

(over)

Soldiers preparing to deploy to Kuwait will be asked to complete a simple health questionnaire. Some soldiers will be selected at random to participate in a breathing test (a device will measure how forcefully an individual can exhale), and will be asked to donate a blood specimen (equal to about 5 tablespoons). These tests pose no risk to participants except for any problem arising from a routine blood draw (a needlestick in the arm)--which would be an extremely rare occurrence.

If you are chosen for special testing to represent your unit be aware that your cooperation with this surveillance is important for the preventive health of the entire unit. The tests are designed to detect very subtle responses that the body has when toxic substances are present--well before any disease would occur. Therefore persons not taking part in the special tests are not missing an opportunity to be screened for disease. Instead, the results of your tests will serve as an early marker for the whole group that is located at the same distance from the fires as you.

By signing below you are acknowledging that this surveillance has been explained to you, and that you are willing to take part in the needed measurements. Thank you for your cooperation.

Print name

Signature

Date





REPLY TO
ATTENTION OF

DEPARTMENT OF THE ARMY
U. S. ARMY ENVIRONMENTAL HYGIENE AGENCY
ABERDEEN PROVING GROUND, MARYLAND 21010-5422



HSHB-ML-O

FINAL REPORT
KUWAIT OIL FIRE HEALTH RISK ASSESSMENT
NO. 39-26-L192-91
5 MAY - 3 DECEMBER 1991

APPENDIX G
SAND AND AMBIENT AJR SAMPLE ANALYSIS

Volume I

I. **PURPOSE.** As part of the **overall** environmental **sampling** and analysis effort to assess the health risk from oil well fires to U.S. troops involved **in Operation** Desert Storm, sand samples, ambient particulate matter less than 10 micrometers (**PM-10**) samples and industrial hygiene samples were analyzed by **RJ Lee Group** using a **variety** of analytical techniques. The purpose of the analyses was to provide a detailed **characterization** of particulate matter comprising each sample to be used as part of a detailed human health risk assessment related to U.S. military and Department of Defense (DOD) civilian exposures to contaminants associated **with** the burning **oil wells**.

II. **REFERENCES.** A list of references used in this Appendix is contained in Annex G-1.

III. **BACKGROUND.**

A. **Project Scope.** This report contains a summary of work completed by **RJ Lee Group** under subcontract to the U.S. Army (Contract Nos. **DAAD-05-92-C-0041** and **DAAD05-93-C-0285**). The project's purpose, as **outlined** above, was to provide a **detailed characterization** of particulate matter on a set of sand **samples**, **PM-10 samples** and **industrial hygiene samples**. Results obtained from **these** analyses were used to provide insight on **the** nature of particulate matter related to **the burning** oil wells that **affected** ambient **air** quality in Kuwait and Saudi **Arabia**.

B. **Appendix Format and Contents.** The following sections of this **appendix** contain general background information concerning the **types** of samples **that** were collected, dates and locations where the samples were **collected**, and **the types** of analyses that **were**

performed on the samples: Paragraph IV details the specific analyses performed on each sample and summarizes the results obtained. Paragraph V discusses the results and identifies trends in the data. Recommendations for future work are provided in Paragraph VI.

C. General Information.

1. At the request of the U.S. Army Surgeon General, an air sampling program was developed by the U.S. Army Environmental Hygiene Agency (USAEHA) to determine the magnitude and extent of pollutants released to the atmosphere from the burning oil wells. Sampling began in Kuwait and Saudi Arabia in early May 1991 and continued through December 1991. As part of this sampling effort, PM-10 samples were collected using high-volume samplers at nine sites which are identified in Table G-1. In an effort to further assess ambient air quality in the region, additional PM-10 samples were collected in November 1993 at the Khobar and Camp Thunderrock sites. These additional samples provide information on ambient air quality under more typical conditions (i.e., baseline data) which can be used to help differentiate the inhalation risk posed by the oil well fires from those potentially already existing in the region.

TABLE G-1. **PM-10 SAMPLING LOCATIONS IN KUWAIT AND SAUDI ARABIA**

<u>Sampling Site</u>	<u>Location</u>	<u>Sampling Period</u>
Khobar Towers	Al-Dhahran, Saudi Arabia	6 May - 2 Dec 1991
camp 1	Al-Jubayl, Saudi Arabia	8 May - 4 Aug 1991
KKMC	King Khalid Military City, Saudi Arabia	19 May - 25 Aug 1991
Eskan Village	Ar-Riyadh, Saudi Arabia	25 May - 25 Aug 1991
Military Hospital	Kuwait city, Kuwait	17 May - 2 Dec 1991
u s Embassy	Kuwait City, Kuwait	19 May - 15 Jul 1991
Camp Thunderrock	Doha, Kuwait	6 Jun - 2 Dec 1991
Ahmadi Hospital	Al-Ahmadi, Kuwait	6 Jun - 6 Jul 1991
Camp Abdaly	Abdaly, Kuwait	19 May - 5 Jun 1991
Khobar Towers	Al-Dhahran, Saudi Arabia	3 Nov - 9 Nov 1993
Camp Thunderrock	Doha, Kuwait	2 Nov - 7 Nov 1993

A subset of the PM-10 samples was analyzed by atomic absorption (AA) spectroscopy, inductively coupled plasma (ICP) spectroscopy and ion chromatography (IC) to document the concentrations of the following twelve elements of interest: antimony (Sb), arsenic (As), bromine (Br), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), strontium (Sr), vanadium (V), zinc (Zn), and zirconium (Zr). These elements were selected

for analysis to assist with the health risk assessment. In addition, **several** of the elements (Le., V, Ni and **As**) are found as impurities in **Kuwaiti** crude oil. Thus, the use of these elements as "tracers" or "markers" can provide insight on the impact of the oil well fires on ambient air quality. Microscopic techniques consisting primarily of computer-controlled scanning electron microscopy (CCSEM) and transmission electron microscopy (**TEM**) were used on a subset of PM-10 samples to provide particle mass distribution data and **particle-type** data. The microscopic data were also used to assess the impact from the oil well fires because carbon-chain agglomerates, which were easily identified using these techniques, provided a good tracer of the plumes. Thermal/optical **methods** were also used on a subset of PM-10 samples to provide information on the organic **carbon** (OC) and elemental carbon (EC) components. These data were also of value in assessing the impact from oil well fires **because** the EC **data** can be **used** as an **indicator** of the soot emissions associated with the plumes. Since Cr was of concern due to potential **carcinogenic** risk, **methods** based on A4 analysis were **utilized** to permit **quantification** of **hexavalent** Cr. Microscopic data were also used to assist in the **speciation** of Cr.

2. Industrial hygiene air sampling and analysis were performed to monitor and characterize occupational exposures to DOD **service** members who had potential high-risk exposure to the oil fire emissions. Samples were initially collected at various locations within Kuwait and Saudi Arabia from May to June 1991. Additional samples were collected in October and November 1991. Table G-2 lists the locations where the industrial hygiene air samples were collected. Similar to the PM-10 samples, a subset of samples was analyzed by GA, ICP and IC to document the concentrations of Sb, **As**, Br, Cd, Cr, Pb, Hg, Ni, **Sr**, V, **Zn** and **Zr**. The CCSEM and TEM techniques were **used** to provide particle mass distribution and particle-type data. Manual scanning electron microscopy (**SEM**) techniques were used to identify and analyze high atomic **number** particles (e.g., V and higher). A subset of samples were **also analyzed** by Fourier transform **infrared** (**FTIR**) spectroscopy and gas chromatography/mass spectroscopy (**GC/MS**) techniques to document the levels of **semi-volatile organic compounds**, **polycyclic** aromatic hydrocarbons, **polycyclic** nuclear hymns, **halogenated** organic compounds and **nitrosamines**.

3. Soil (**sand**) samples were collected and analyzed as **part** of the multimedia sampling effort to assist in **the** assessment of health risk from oil well **fires** to **U. S.** troops involved in Operation Desert Storm. Samples were collected at various locations in Kuwait and Saudi Arabia during May through Sep 1991. Additional samples were collected in Nov 1993. Subsets of the 1991 and 1993 samples were **analyzed** by CCSEM to provide particle mass distribution and particle-type data. The 1993 samples were also analyzed by AA, ICP and IC to document the levels of Sb, As, Br, Cd, Cr, Pb, Hg, **Ni**, Sr, V, **Zn** and Zr. In addition, the **sand** samples collected in 1993 were analyzed for hexavalent chromium using methods based on **AA** analysis. Tables G-3 and **G-4** list the locations **in** Kuwait and Saudi

TABLE G-2. INDUSTRIAL HYGIENE **SAMPLING** LOCATIONS IN SAUDI **ARABIA**
AND KUWAIT

Sampling Site	Location	Operation
Khobar Towers	Al-Dhahran, Saudi Arabia	Residential/Guards
Northwest Jubayl	Al-Jubayl, Saudi Arabia	Supply Points
826 Ordnance Loading	Al-Jubayl, Saudi Arabia	Ammunition
Jubayl Port Area Handling	Al-Jubayl, Saudi Arabia	Equipment
Damman Port Area Handling	Damman, Saudi Arabia	Equipment
Camp Freedom	Subhan, Kuwait	Residential/Guards
EOD Safe Holding Area Storage	Camp Freedom, Kuwait	Ammunition
US Embassy	Kuwait City, Kuwait	Guards
Military Hospital	Kuwait City, Kuwait	Guards
Ahmadi Hospital	Al-Ahmadi, Kuwait	General Area
Camp Thunderrock	Doha, Kuwait	Guards
Gathering Center 1	Burgan Oil Field, Kuwait	Field Work
Gathering Center 2	Burgan Oil Field, Kuwait	Field Work
Road Intersection	Al Wafra, Kuwait	General Area

TABLE G-3. SAND SAMPLE **IDENTIFICATIONS** AND **COLLECTION** DATES - 1991
SAMPLES

Sampling Site	Location	Date Collected
Camp Freedom	Subhan, Kuwait	10 May 1991
Khobar	Al-Dhahran, Saudi Arabia	14 May 1991
KKMC	King Khalid Military City, Saudi Arabia	18 May 1991
Camp Freedom	Subhan, Kuwait	30 May 1991
Khobar	Al-Dhahran, Kuwait	12 sep 1991

TABLE G-4. SAND SAMPLE IDENTIFICATIONS AND COLLECTION DATES - 1993
SAMPLES

Sampling Site	Location	Date Collected
Camp Thunderrock	Doha, Kuwait	3 Nov 1993
US Embassy	Kuwait City, Kuwait	4 Nov 1993
Camp Freedom	Subhan, Kuwait	5 Nov 1993
Ahmadi Hospital	Al-Ahmadi, Kuwait	5 Nov 1993
Military Hospital	Kuwait City, Kuwait	5 Nov 1993
Khobar	Al-Dhahran , Saudi Arabia	7 Nov 1993
Camp 1	Al-Jubayl, Saudi Arabia	8 Nov 1993
Camp 1	Al-Jubayl, Saudi Arabia	8 Nov 1993

Arabia where the 1991 and 1993 samples were collected. The data obtained from the soil **sampling** and analysis effort were combined with the air monitoring data to provide for a comprehensive health risk assessment that **evaluated all** pathways/routes of exposure.

IV. ANALYTICAL METHODOLOGY AND RESULTS.

A. Sand Samples.

1. Metals and Bromine Analysis. Seven samples **collected** by **USAEHA** personnel in Nov 1993 from the top several inches of sand at Camp **Thunderrock**, U.S. Embassy, Camp Freedom, **Ahmadi** Hospital, Military Hospital, **Al-Dhahran** and Al-Jubayl and one composite sample collected at Al-Jubayl were analyzed for eleven metals (i.e., Sb, **As**, Cd, Cr, Pb, Hg, **Ni**, Sr, V, **Zn**, and **Zr**) and Br.

a. Antimony, **arsenic**, **cadmium**, chromium, nickel, **strontium** and vanadium were analyzed using a **Varian Model 400** Graphite **Furnace** Atomic Absorption (**GFAA**) Spectrometer with a **Zeeman** background **correction**. **Lead** and zinc were analyzed by **GFAA** on a **Varian Model 400** or by Flame Atomic Absorption (**FLAA**) Spectroscopy on a Varian Model **300**, depending on the level of **analyte encountered**. Extracts of sand were prepared for these analyses following the U.S. Environmental **Protection** Agency (EPA) Method 3050. Briefly, sand was **extracted** in fuming nitric acid followed by a final dilution to 50 mL in 4% nitric acid. The elements were analyzed following methods **listed** in Table G-5.

TABLE G-5. ANALYTICAL METHODS USED FOR EACH ELEMENT AND LIMITS OF QUANTITATION

Element	Method	Instrumentation	Limit of Quantitation*
Antimony (Sb)	EPA SW846-3050/7041	GFAA	50.0 ppb
Arsenic (As)	EPA SW846-3050/7060	GFAA	5.0 ppb
Bromine (Br)	NIOSH 7903	IC	0.6 ppm
Cadmium (Cd)	EPA SW846-3050/7131	GFAA	5.0 ppb
Chromium (Cr)	EPA SW846-3050/7191	GFAA	5.0 ppb
Lead (Pb)	EPA SW846-3050/7420	FLAA	0.1 ppm
Lead (Pb)	EPA SW846-3050/7421	GFAA	5.0 ppb
Mercury (Hg)	EPA SW846-7471A	CVAA	0.5 ppb
Nickel (Ni)	EPA SW846-3050/7520	GFAA	5.0 ppb
Strontium (Sr)	EPA SW846-3050/7000A	GFAA	5.0 ppb
Vanadium (V)	EPA SW846-3050/7911	GFAA	10.0 ppb
Zinc (Zn)	EPA SW846-3050/7950	FLAA	50.0 ppb
Zinc (Zn)	EPA SW846-3050/7951	GFAA	5.0 ppb
Zirconium (Zr)	NIOSH 7300	ICP	5.0 ppb

* Limit in final extraction solution.

b. Samples were analyzed for Hg following EPA Method 7471A. With this method, samples were extracted in a mixture of nitric and sulfuric acid containing potassium sulfate and potassium permanganate at 95 °C. These extracts were analyzed using a Varian Model 300 Atomic Absorption Spectrometer with a cold vapor generator (CVAA).

c. To improve the level of detection for Zr over the standard AA method (reference 1), a method was developed by RJ Lee Group for analysis of extract solutions using an ultrasonic nebulizer with ICP (reference 2). A Spectro Analytical Model D ICP was monitored at a wavelength of 339.20 nm for these analyses. Details of the method are described in Volume II of this report.

d. Samples were analyzed by IC for Br. National Institute for Occupational Safety and Health (NIOSH) Method 7903 was used for this analysis. Samples were prepared by extraction with carbonate/bicarbonate IC eluent. Extracts were analyzed on a Dionex Model 2120i Ion Chromatograph using an Ionpac AS4 separation column and a Micromembrane Anion suppressor column from Dionex.

e. Table G-5 lists the preparation/analytical methods used in this study and the quantitation limits for the final extraction solution for each element. Sample concentrations for each element were based on calibration curves generated from certified reference standards and verified against independent reference materials. Details of the methods used for each element in this assessment are described in Volume II of this report.

f. Maximum observed levels of each metal in the sand samples can be found in Table G-6. Strontium was present at the highest levels of the metals investigated, ranging from 103.0 µg/g at Camp Freedom to 2255.3 µg/g at Camp Thunderrock. Antimony, bromine, cadmium and mercury levels were all below quantitation limits. Arsenic, chromium, nickel, vanadium and zirconium varied from site to site by less than about 40% relative standard deviation (RSD). Strontium showed the greatest variation amongst the sites (125% RSD) whereas lead had the next greatest variation at 69% RSD. The complete data set is provided in Table G-2-1 in Annex G-2.

TABLE G-6. MAXIMUM OBSERVED METAL CONCENTRATIONS IN SAND SAMPLES

Element*	Sample Location Site	Date Collected	Concentration (µg/g)
Vanadium	Ahmadi Hospital, Kuwait	5 Nov 1993	16.7
Chromium	Ahmadi Hospital, Kuwait	5 Nov 1993	24.8
Nickel	Camp Thunderrock, Kuwait	3 Nov 1993	16.6
Zinc	us Embassy, Kuwait	4 Nov 1993	49.6
Strontium	Camp Thunderrock, Kuwait	3 Nov 1993	2255.3
Zirconium	Ahmadi Hospital, Kuwait	5 Nov 1993	1.3
Arsenic	Camp Thunderrock, Kuwait	3 Nov 1993	3.3
Lead	A 1-Jubayl, Saudi Arabia	8 Nov 1993	18.6

* Antimony, bromine, cadmium and mercury were below limits of quantitation.

2. Hexavalent Chromium. Sixty bulk sand samples were collected in Kuwait and Saudi Arabia by **USAEHA** personnel between 2 November 1993 and 8 November 1993. Approximately 20 grams of each **sand** sample was extracted in the field with water and charged onto solid-phase cartridges containing a hexavalent chromium-specific **ligand** following **procedures** developed at RJ Lee Group. Cartridges were prepared prior to field sampling at **RJ Lee** Group according to the procedures described by Morocco, et al. (reference 3). The bulk sand samples, contained in zipper-lock plastic bags, were kept as retention samples. Seven additional sand samples were **spiked** with **hexavalent** chromium in the field and also **charged** onto solid phase **cartridges**. Sixty-seven cartridges obtained from charging sixty sand samples and seven spiked-sand samples were **sealed** in zipper-lock plastic bags, stored at or below refrigerated temperatures, and **shipped** at similar temperatures to the **USAEHA** facility in **Aberdeen, Maryland**. Samples were transferred to **RJ Lee** Group on 18 November 1993. Refer to **Tables G-2-2 through G-2-5** in Annex G-2 for identification of the **cartridges** and sand samples.

a. **Hexavalent** chromium was **eluted** from cartridges with **n-butanol**. **Eluants** along with **eluants** from blank and hexavalent chromium standard reference material SRM-2109 (reference 4) spiked cartridges were analyzed on a **Varian Model 400 GFAA** with **Zeeman background correction** following EPA Method **SW846-7191**. Sample concentrations were based on calibration **curves** generated from the blank and SRM-2109 spiked cartridge eluants. The limit of quantitation for **water-extractable** hexavalent chromium was determined to be 5.0 parts per billion (**ppb**) for a 20 **gram** sample. No **sand** sample analyzed for hexavalent chromium showed **quantifiable** levels of this ionic specie.

b. Water extracts of the retention samples described in paragraph **VIB2** were analyzed on **GFAA** following EPA **Methods SW846-3050/7191**. The limit of quantitation for water extractable total Cr was determined to **be** 17.9 ppb for a 20 gram sample. No **sand** sample analyzed showed **quantifiable** levels of **water-extractable** chromium. In contrast to the **water-extractable** Cr, extraction with **fuming** acid, as described in **paragraph IVA.1a**, reported chromium ranging from 3 to 25 ppb (refer to Table G-2-1 in Annex G-2). Microscopic analysis detect.4 stainless **steel** particles on the **filters** which would help explain these **findings**.

c. **Water-extractable** total and hexavalent chromium results for the sand samples are provided in Tables G-2-6 and G-2-7 in Annex G-2.

d. In addition to the field samples, **USAEHA** field personnel charged seven **cartridges** with extracts from seven **different** sand samples which they had spiked in the field with hexavalent chromium at various levels. Recovery of hexavalent chromium from six of the field spiked samples averaged 120.3 f29.6 %. Results for the seventh sample are not

reported due to missing field data. A summary of the results for the six spiked samples is shown in Table G-2-8 in Annex G-2. Details on validation of this method are provided in Volume II of this report.

3. Particulate Composition and Sizing. Samples of soil (sand) were collected by USAEHA personnel from several sites in Kuwait and Saudi Arabia from May 1991 through September 1991. Additional samples were collected in November 1993. The 1991 samples that were received for analysis by microscopic techniques are summarized in Table G-7. The 1993 samples that were analyzed by microscopic techniques for particulate composition and sizing are identified in Table G-8.

TABLE G-7. SAND SAMPLE IDENTIFICATIONS AND COLLECTION DATES - 1991 SAMPLES

Sampling Site	Location	Date Collected	USAEHA Identification	USAEHA Lab. No	RJ Lee Group Sample No.
Camp Freedom	Subhan, Kuwait	10 May 1991	CF-5A	Y2189	601464
Khobar	Al-Dhahran, Saudi Arabia	14 May 1991	DA-4A	Y2173	601466
KKMC	KKMC, Saudi Arabia	18 May 1991	KK-4A	Y2168	601468
Camp Freedom	Subhan, Kuwait	30 May 1991	CF-6A	Z2190	601465
Khobar	Al-Dhahran, Saudi Arabia	12 Sep 1991	DA-1B-7	21670	601467

TABLE G-8. SAND SAMPLE IDENTIFICATIONS AND COLLECTION DATES - 1993 SAMPLES

Sampling Site	Location	Date Collected	USAEHA sample Identification	RJ Lee Group Sample No.
Camp Thunderrock	Doha, Kuwait	3 Nov 1993	Big CT	605192
US Embassy	Kuwait City, Kuwait	4 Nov 1993	Big EM	605194
Camp Freedom	Subhan, Kuwait	5 Nov 1993	Big CF	605191
Ahmadi Hospital	Al-Ahmadi, Kuwait	5 Nov 1993	Big AH	605189
Military Hospital	Kuwait City, Kuwait	5 Nov 1993	Big MH	605195
Khobar	Al-Dhahran, Saudi Arabia	7 Nov 1993	Big DA	605193
Camp 1	Al-Jutmyl, Saudi Arabia	8 Nov 1993	Big AJ	605190
Camp 1	Al-Jubayl, Saudi Arabia	8 Nov 1993	AJ Composite	605063

a. Details of the preparation and analytical methods used are found in Volume II of this report. Briefly, the samples were first sieved through a 90 μm (170 mesh) screen. The < 90 μm fraction was then sieved again using a 38 μm (400 mesh) screen. The < 38 μm fraction was prepared and analyzed for size and particle-type information by CCSEM.

b. Mass distribution results based on aerodynamic equivalent diameter for the < 38 μm fraction are reported in Tables G-2-9 and G-2-10 in Annex G-2, showing the bulk of the mass to be in the > 10 μm aerodynamic size range.

c. Particle-type results are presented in Tables G-2-11 and G-2-12 in Annex G-2. These results indicate that mixed clays, silicon-rich and calcium-rich particles were the dominant types found in the samples.

d. The sand samples collected in 1993 were examined using TEM methods. The primary purpose of the TEM examination was to document whether carbon-chain agglomerate particles were present in the samples. Although carbon-chain agglomerates were observed in most samples, they were present at very low levels and would have a negligible effect on the overall sample mass.

B. **PM-10 Samples.** Forty-eight high-volume PM-10 samples, twenty-five collected in 1991 and twenty-three collected in 1993, were analyzed for eleven metals (i.e., Sb, As, Cd, Cr, Pb, Hg, Ni, Sr, V, Zn, and Zr), Br and hexavalent chromium. Table G-2-13 in Annex G-2 identifies the samples analyzed and gives the collection date for each filter. Subsets of these samples were also analyzed by thermal/optical and microscopic techniques. Filters were sectioned for the various types of analyses (GFAA, ICP, CVAA, IC, hexavalent chromium, thermal/optical and microscopic) using plastic (non-metallic) scissors to avoid contamination from metal particles during cutting.

1. Metals and Bromine. For the GFAA, FLAA, and ICP analyses, the size of filter sections in square inches was recorded. A section from each sample was then extracted in fuming nitric acid according to EPA Method SW846-3050 followed by dilution in 4% nitric acid. Samples were prepared and analyzed for Br and Hg using IC and CVAA methods as described in paragraph IVA1 for sand. Analysis of extracts were performed for metals and bromine as described for the sand samples.

a. The average concentrations of metals detected on PM-10 filters collected in Camp Thunderrock and Khobar in 1991 and 1993 are shown in Table G-9. Maximum observed levels of each metal for the samples collected in 1991 and 1993 are tabulated in Tables G-10 and G-11. It should be noted that the 1991 PM-10 samples were collected over a 24-hour period, whereas the 1993 samples were collected over a 12-hour period. The 1993 samples were collected over a shorter time period in an attempt to provide a better sample for microscopic analysis. In summary, the levels of all metals were low (i.e., ng/m³ levels). Many of the metals and Br were found to be at or below the level of quantitation. With the exception of Pb at Khobar, the average levels of metals observed for samples collected at Camp Thunderrock and Khobar in 1991 were higher than for those collected at the same sites in 1993. Other than for Cd, which was detected near the limit of quantitation, the maximum

levels of each element were greater in 1991 than 1993 as **can be** observed in Tables G-10 and G-11. The complete data set for metals and Br is presented in Tables G-2-14 and G-2-15 in Annex G-2.

b. Electron microscopic examination of several PM-10 samples, showed that lead particles were consistent with automotive emissions from leaded fuel (refer to paragraph IVB4g).

c. Concentrations of Ni and V reported here are consistent with other published data for similarly loaded **filters**. Cahill et al. (reference 5) reported values of 5 to 21 **ng/m³** and 9 to 27 **ng/m³** for Ni and V collected in plumes 2000 meters in elevation at a distance of about 200 to 250 km downwind of the fires. **Madany** and **Raveendran** (reference 6) reported average concentrations of 22 and 26 **ng/m³** for **Ni** and V collected in ground-level samples in Bahrain, approximately 320 **km** downwind from the fires.

TABLE G-9. AVERAGE OBSERVED ELEMENTAL CONCENTRATIONS ON PM-10 SAMPLES COLLECTED IN 1991 AND 1993 (ng/m³)

Element*	Camp Thunderrock		Khobar	
	1991 ⁺	1993 [≠]	1991 [§]	1993 ^{**}
Antimony	23.7	BLQ	14.7	BLQ
Arsenic	3.0	BLQ	2.7	BLQ
Chromium	21.2	5.7	15.9	7.6
Lead	162.4	34.6	185.3	309.7
Mercury	0.7	BLQ	0.6	BLQ
Nickel	15.5	7.8	20.2	10.1
Strontium	109.4	16.3	• 118.4	26.3
Vanadium	20.7	5.1	18.0	5.9
Zinc	93.0	57.6	116.1	81.9
Zirconium	3.6	BLQ	3.1	BLQ

• Bromium and cadmium were below limit of quantitation (BLQ)

+ Average of 4 samples

≠ Average of 13 samples

§ Average of 6 samples

• - Average of 10 samples

TABLE G-10. MAXIMUM OBSERVED METAL CONCENTRATIONS ON PM-10 SAMPLES COLLECTED IN 1991

Element*	Sample Location Site	Date Collected	concentration (ng/m ³)
Antimony	US Embassy, Kuwait	m Jun 1991	33.1
Arsenic	Military Hospital, Kuwait	5 Jun 1991	5.9
Chromium	Military Hospital, Kuwait	17 Jun 1991	74.8
Lead	Military Hospital, Kuwait	12 Oct 1991	753.9
Mercury	US Embassy, Kuwait	20 Jun 1991	2.0
Nickel	US Embassy, Kuwait	17 Jun 1991	53.7
Strontium	US Embassy, Kuwait	17 Jun 1991	198.3
Vanadium	us Embassy, Kuwait	m May 1991	46.0
zinc	Khobar, Saudi Arabia	29 Jul 1991	275.4
Zirconium	Eskan Village, Saudi Arabia	m Jun 1991	9.0

* Bromine and Cadmium were at or BLQ

TABLE G-11. MAXIMUM OBSERVED METAL CONCENTRATIONS ON PM-10 SAMPLES COLLECTED IN 1993

Element*	Sample Location Site	Date Collected	Concentration (ng/m ³)
Arsenic	Camp Thunderrock, Kuwait	4 Nov 1993	3.2
Cadmium	camp Thunderrock, Kuwait	7 Nov 1993	3.5
Chromium	Khobar, Saudi Arabia	7 Nov 1993	8.6
Lead	Khobar, Saudi Arabia	4 Nov 1993	416.4
Mercury	Khobar, Saudi Arabia	7 Nov 1993	1.0
Nickel	Camp Thunderrock, Kuwait	4 Nov 1993	12.5
Strontium	Khobar, Saudi Arabia	5 Nov 1993	71.6
Vanadium	Khobar, Saudi Arabia	4 Nov 1993	6.4
Zinc	Khobar, Saudi Arabia	7 Nov 1993	106.0
Zirconium	Camp Thunderrock, Kuwait	6 Nov 1993	2.6

• Antimony was BLQ for all samples in 1993

2. **Hexavalent** Chromium. The 48 PM-10 filter samples analyzed for metals and bromine were **also** analyzed for **water-extractable total** and **hexavalent** chromium. A list of the samples analyzed is provided in Table G-2-13 in Annex G-2.

a. The **preparation** methodology for these samples was adapted from the method evaluated by Morocco, et al. (reference 3) for analysis of water samples for hexavalent chromium. Briefly, filter portions were soaked and shaken in double deionized water washes followed by filtration **through** a paper **filter** and charging onto solid phase cartridges containing a hexavalent chromium specific **ligand**. **Hexavalent** chromium was eluted from cartridges with n-butanol. These **eluants** along with **eluants** from blank and spiked cartridges were analyzed on **GFAA** following EPA Method **SW846-7191**. Results of these analyses showed no hexavalent chromium present above the quantitation limit of, at most, 0.8 ng/m^3 on any filter.

b. Prior to charging, an **aliquot** of the extract was set aside for total water extractable chromium analysis by EPA **Method SW846-7191**. Water extractable chromium was only detected in 4 out of the **48** samples analyzed and **all** four values were less than 8.0 ng/m^3 .

c. Water-extractable total chromium and hexavalent chromium results for the PM-10 samples are provided in Tables G-2- 16 and G-2-17 in Annex G-2.

d. To investigate the background levels of Cr in quartz and glass-fiber filters, blank **filters** were extracted with water, nitric acid, or **nitric** plus hydrofluoric acids. Water extracts showed Cr below the quantitation limit of $0.02 \text{ } \mu\text{g/in}^2$. Fuming nitric acid extracted Cr on the order of $0.2 \text{ } \mu\text{g/in}^2$ and nitric acid followed by hydrofluoric acid extracted $0.8 \text{ } \mu\text{g/in}^2$ of Cr. Electron microscopic examination of these blank filters detected particles of stainless **steel**, which **could explain** the background levels of acid-extractable Cr observed (*see* paragraph IVB4g).

3. Elemental Carbon. Thirty-four PM-10 samples **from** eight sampling sites were analyzed for organic carbon, elemental carbon, and inorganic **carbonate** using **thermal/optical** methods by Sunset Laboratory, Forest Grove, Oregon under **subcontract** to **RJ Lee** Group. A list of the samples analyzed along with the **results** is provided in Table G-2-18 in Annex G-2.

a. The **thermal/optical** analysis was **performed** in an oxygen-free helium atmosphere. Each sample was heated in four temperature steps to remove all the organic carbon present. **As** the organic compounds were vaporized, they were immediately oxidized to carbon dioxide in an oxidizing oven. The **optical** absorbance of the sample was monitored continuously with a helium-neon (He-Ne) laser. By monitoring the **optical** absorbance of the sample, organic **compounds** which are **pyrolytically** converted to **elemental carbon** can be determined. The flow of helium containing carbon dioxide was sent to a **methanator** oven where it was converted to methane which was then **detected** by a flame ionization detector. Elemental carbon was determined by cooling the oven to $525 \text{ }^\circ\text{C}$ and switching to a 2 percent oxygen/helium mixture. This was followed by **increasing** the temperature to $600 \text{ }^\circ\text{C}$ and

then 700 °C. During this phase, both the original elemental **carbon** and that produced by the pyrolysis of **organics** during the first phase are oxidized to **carbon** dioxide, followed by detection using flame ionization. Again, the darkness of the filter is continuously monitored using the He-Ne laser. **After** carbon has **been** oxidized from the sample, a known volume of a **known** mixture of methane is injected into the sample oven as an **internal** standard.

b. The elemental carbon results provide insight on the impact of oil **fire** emissions on ambient air quality **because soot** in the plumes is elemental carbon **in** the form of small carbon-chain agglomerate particles (reference 7).

c. **Thermal/optical** data **indicate** that elemental carbon (soot) results **ranged** from a low of 0.5 $\mu\text{g}/\text{m}^3$ at Camp **Thunderrock** (5 November 1993) to a high of 198.5 $\mu\text{g}/\text{m}^3$ at **Ahmadi** Hospital (20 June 1991).

d. Elemental **carbon** in the **Khobar** samples **ranged** from 0.9 $\mu\text{g}/\text{m}^3$ to 30.6 $\mu\text{g}/\text{m}^3$ with an average of 11.5 $\mu\text{g}/\text{m}^3$ (six samples) during the **period** from 23 **May** 1991 to 15 October 1991. Samples collected at the same site between 3 November 1993 and 7 November 1993 ranged from 1.1 $\mu\text{g}/\text{m}^3$ to 1.9 $\mu\text{g}/\text{m}^3$ with an average of 1.6 $\mu\text{g}/\text{m}^3$ (six samples).

e. At Camp **Thunderrock**, elemental carbon ranged from 1.7 $\mu\text{g}/\text{m}^3$ to 53.8 $\mu\text{g}/\text{m}^3$ with an average of 25.0 $\mu\text{g}/\text{m}^3$ (four samples) during the **period** from 11 June 1991 to 12 October 1991. From 3 November 1993 to 7 November 1993, results ranged from 0.5 $\mu\text{g}/\text{m}^3$ to 3.6 $\mu\text{g}/\text{m}^3$ with an average of 2.0 $\mu\text{g}/\text{m}^3$ (six samples).

f. Results obtained from the **thermal/optical** analysis are **summarized** by sample location site **in** Figure 1.

g. The elemental **carbon** contained on the 1991 **samples** is similar to that reported in the **literature**, though **data** from Herring and **Hobbs** (reference 8), show considerable spatial **variation** within a plume, and data from **Thibaut** and **Lameloise** (reference 9) show considerable **temporal** variation (in terms of hours) at individual **ground locations**. Although elemental carbon in individual plumes at their source **can be** several hundred to several thousand ng/m^3 (references 9, 10, and 11), data from **Ferek et al.** (reference 11) and Cahill et al. (reference 5) show concentrations **between** 23 and 224 $\mu\text{g}/\text{m}^3$ at distances of 20-250 km downwind of the oil well fires.

4. Particulate Composition and Sizing. A total of 57 high-volume PM-10 samples was received for potential microscopic analysis. **The** samples were collected over two **time** periods. The first set was obtained **between 20 May** 1991 and 15 **October** 1991 when the oil wells were still **burning**. **The** second set was collected from 2 November 1993 to

Thermal/Optical Carb^{so} Analysis

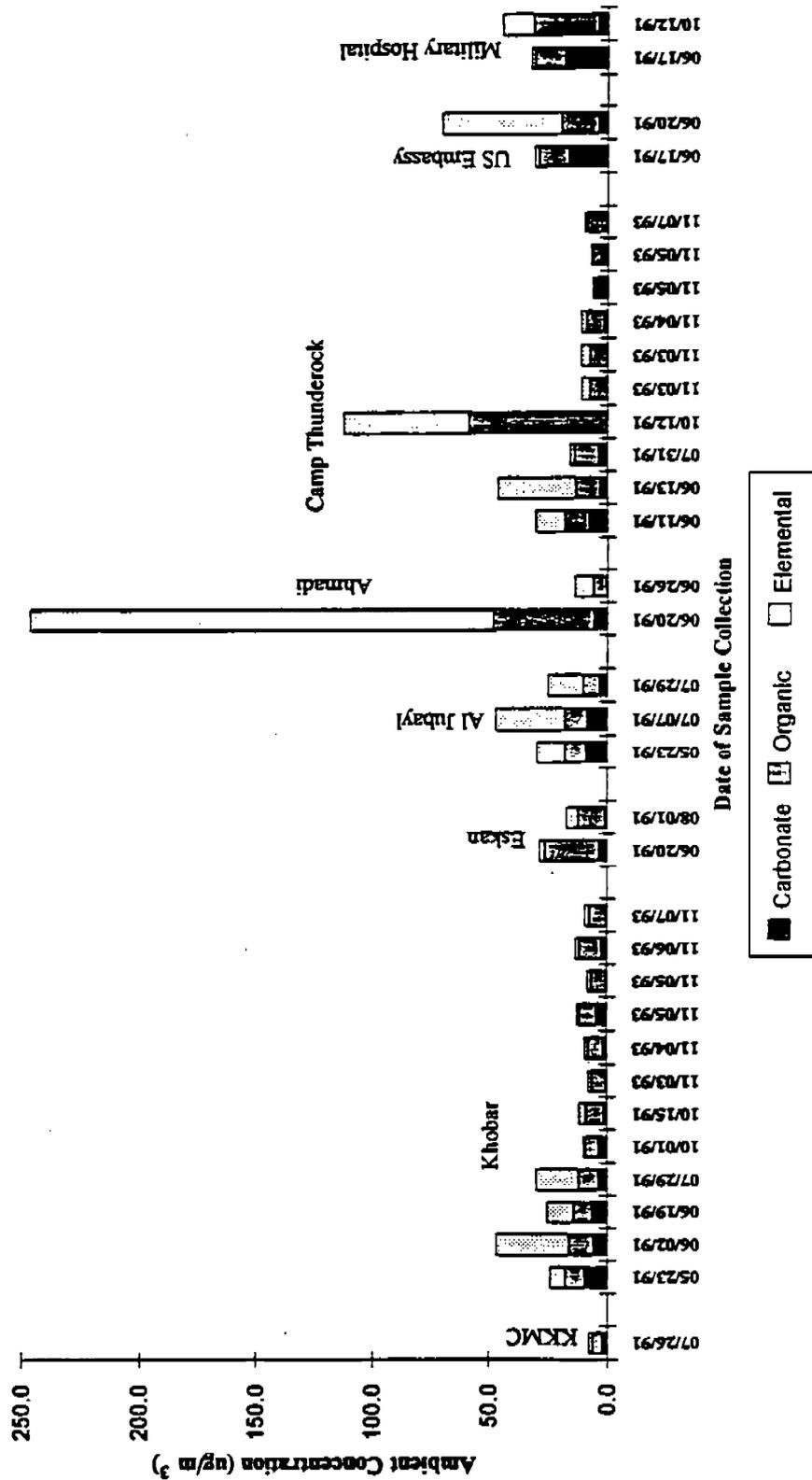


FIGURE 1

9 November 1993. The second sample set was obtained to provide information on ambient air quality under more typical conditions for the region and to help in the assessment of the impact of the oil well fires on ambient air quality. The as-received condition of these samples is listed in Tables G-2-19 through G-2-28 in Annex G-2. Twenty-two of these samples were selected for analysis using a combination of **CCSEM** and **TEM** techniques. The selected samples were collected at **Khobar**, Saudi Arabia and Camp Thunderock, Kuwait. The **CCSEM/TEM** analyses provide information on individual particle size and composition which were used to construct **particle** mass distribution data and particle type summaries. The **CCSEM/TEM** data were also used to provide insight on the impact of the oil well fires on ambient air quality in Kuwait and Saudi Arabia by using the carbon-chain agglomerate particle **type** as a tracer of the oil fires plumes (reference 12).

a. The PM-10 samples were collected on **glass-fiber** and **quartz-fiber filters**. Details on the **preparation** and analysis methods used on these samples are provided in Volume II of this report.

b. Aerodynamic equivalent mass distribution results, as presented in Tables G-2-29 and G-2-30 in **Annex G-2**, **indicate** that the majority of the particle mass for most samples **occurred** in the size ranges less than 10 μm . However, a **significant fraction** of the **particle** mass was observed in the 10 to 30 μm size range for all samples. Several of the samples also reported **significant** mass in the greater than 30 μm size range.

c. Particle-type **data** for the samples are provided in Tables G-2-31 and G-2-32 in Annex G-2. These data **indicate** that mixed clays, silicon-rich and calcium-rich particles account for the vast majority of the sample mass for most samples. These data indicate that the PM-10 material was comprised mainly of sand-based material.

d. Particle-type data **indicate** that **carbon-chain agglomerates** (CCA) generally account for only a small **percentage** of the sample mass for most samples as shown in Tables G-2-33 and G-2-34 in **Annex G-2**. At Khobar, CCA ranged from 0.8 $\mu\text{g}/\text{m}^3$ to 20.5 $\mu\text{g}/\text{m}^3$ with an **average** of 6.9 $\mu\text{g}/\text{m}^3$ (six **samples**) during the **period** from 27 **May** 1991 to 15 October 1991. For comparison purposes, **CCA ranged** from 0.9 $\mu\text{g}/\text{m}^3$ to 5.2 $\mu\text{g}/\text{m}^3$ with an average of 2.7 $\mu\text{g}/\text{m}^3$ (six samples) between 3 November 1993 and 7 November 1993.

e. **At Camp Thunderock, CCA ranged** from 0.5 $\mu\text{g}/\text{m}^3$ to 89.5 $\mu\text{g}/\text{m}^3$ with an average of 31.2 $\mu\text{g}/\text{m}^3$ (four samples) based on samples collected **between** 11 June 1991 and 12 October 1991. During the **period** of 3 November 1992 to 7 November 1993, CCA ranged from 1.2 $\mu\text{g}/\text{m}^3$ to 5.1 $\mu\text{g}/\text{m}^3$ at Camp Thundemck with an average of 3.7 $\mu\text{g}/\text{m}^3$ (six samples).

f. The **CCSEM/TEM** CCA results **compared** well with the elemental carbon results obtained with thermal/optical analysis as illustrated in Figure 2.

g. The four Camp Thunderrock samples collected in 1991 were examined further for the presence of heavy-metal-bearing particles. Of particular interest were uranium particles. **Large areas** of the filter (**between** 10,000 and 35,000 fields at 800X per sample) were examined using **CCSEM** techniques. No uranium particles were detected. However, lead-bromine, stainless steel, strontium and vanadium particles were detected. Figures 3 through 6 provide an image and elemental spectrum of each particle-type.

C. **Industrial Hygiene Sample Analysis.** Mixed cellulose ester (**MCE**), polyvinyl chloride (PVC) and **polycarbonate** (PC) filters collected using personal monitoring samplers were **analyzed** by for metals (i.e., Sb, **As**, Cd, Cr, Pb, Hg, **Ni**, Sr, V, **Zn**, and Zr), Br, organic compounds, and individual particle **size** and composition. Samples were divided into sections to **be** used for the various **preparative** and **analytical** methods. **The areas** or weights of the portions used for chemical analyses were **measured** to facilitate **final** reporting based on whole **filter**.

1. Metals **and** Bromine. Nine filters were analyzed for metals and Br. Table G-12 identifies these filters. Table G-13 lists the methods used for these analyses and the limits of quantitation for each element in the final extract solution.

TABLE G-12. INDUSTRIAL HYGIENE SAMPLES ANALYZED FOR METALS AND BROMINE

USAEHA Field Sample No.	Filter Type	Date Collected	Sample Location Site	USAEHA Lab No.	RJ Lee Group Sample No.
130-04	MCE	10 May 1991	Khobar, Saudi Arabia	Y1109	601456
130-10	MCE	10 May 1991	Khobar, Saudi Arabia	Y1112	603679
T134-20	PVC	14 May 1991	Camp Freedom, Kuwait	N A	601426
135-07	PVC	15 May 1991	Field Blank	NA	601429
T136-04	PVC	16 May 1991	Camp Freedom, Kuwait	NA	601430
137-11	MCE	17 May 1991	Military Hospital, Kuwait	Y1836	6014.60
T140-05	PVC	20 May 1991	Burgan Oil Field, Kuwait	NA	60143s
140-11	MCE	20 May 1991	Burgan Oil Field, Kuwait	Y1837	603693
OF/FB/31	PC	NA	Field Blank	25391	603707

Comparison of Thermal/Optical Elemental Carbon Results to CCSEM/TEM Carbon Chain Agglomerate Data

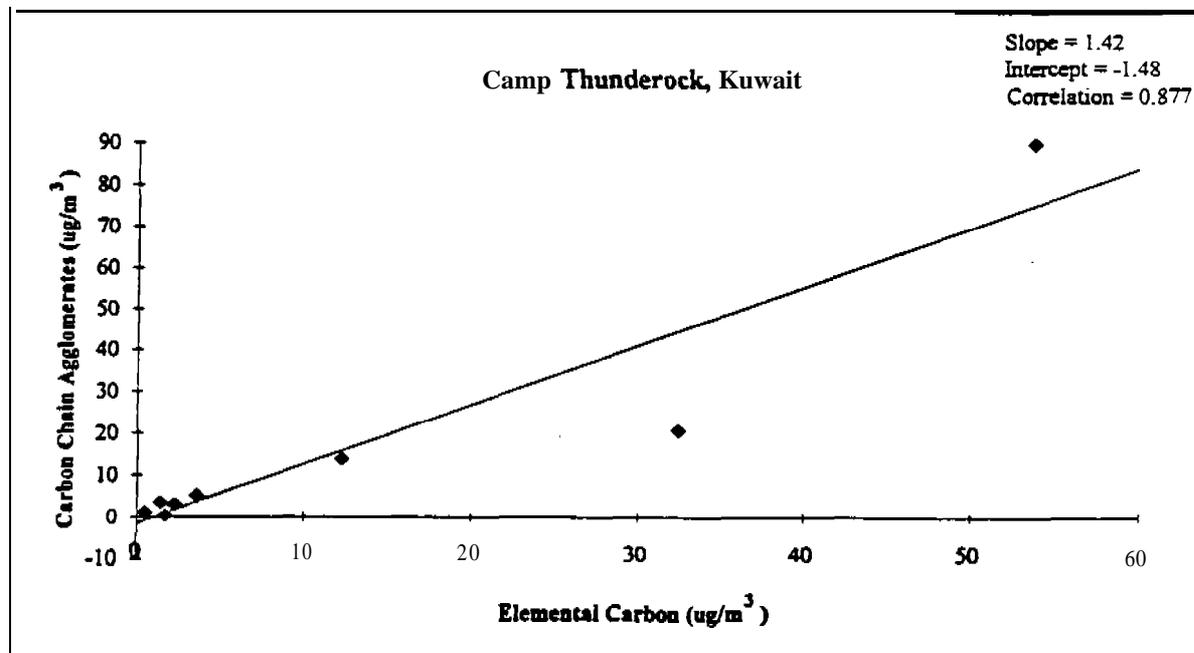
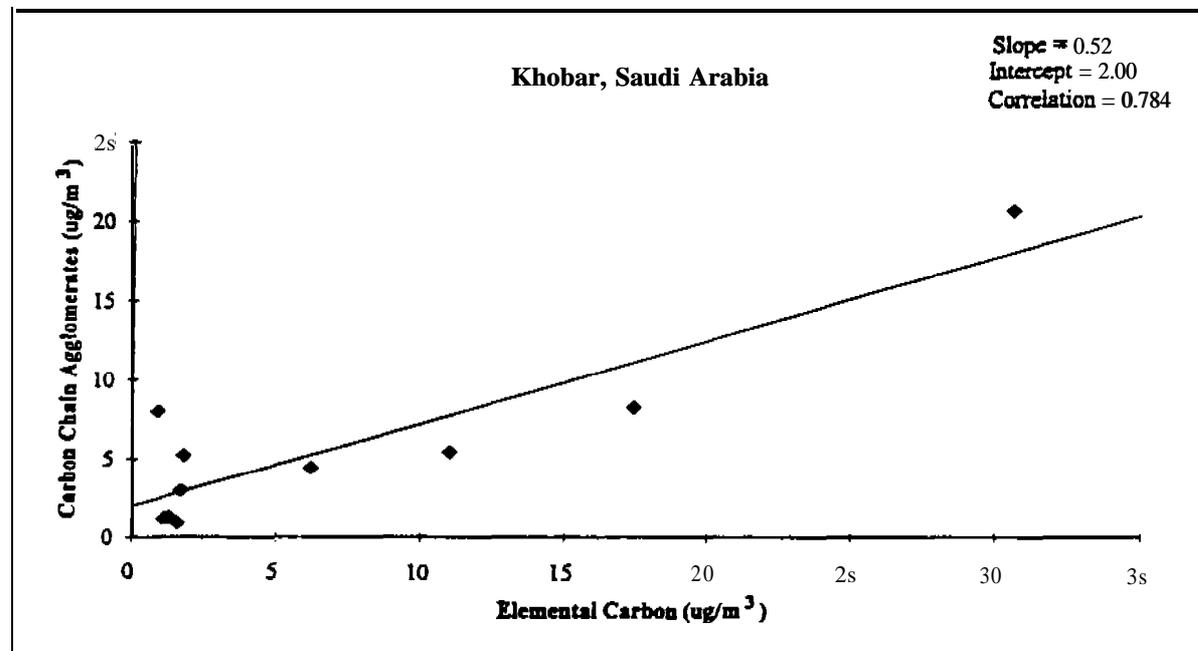
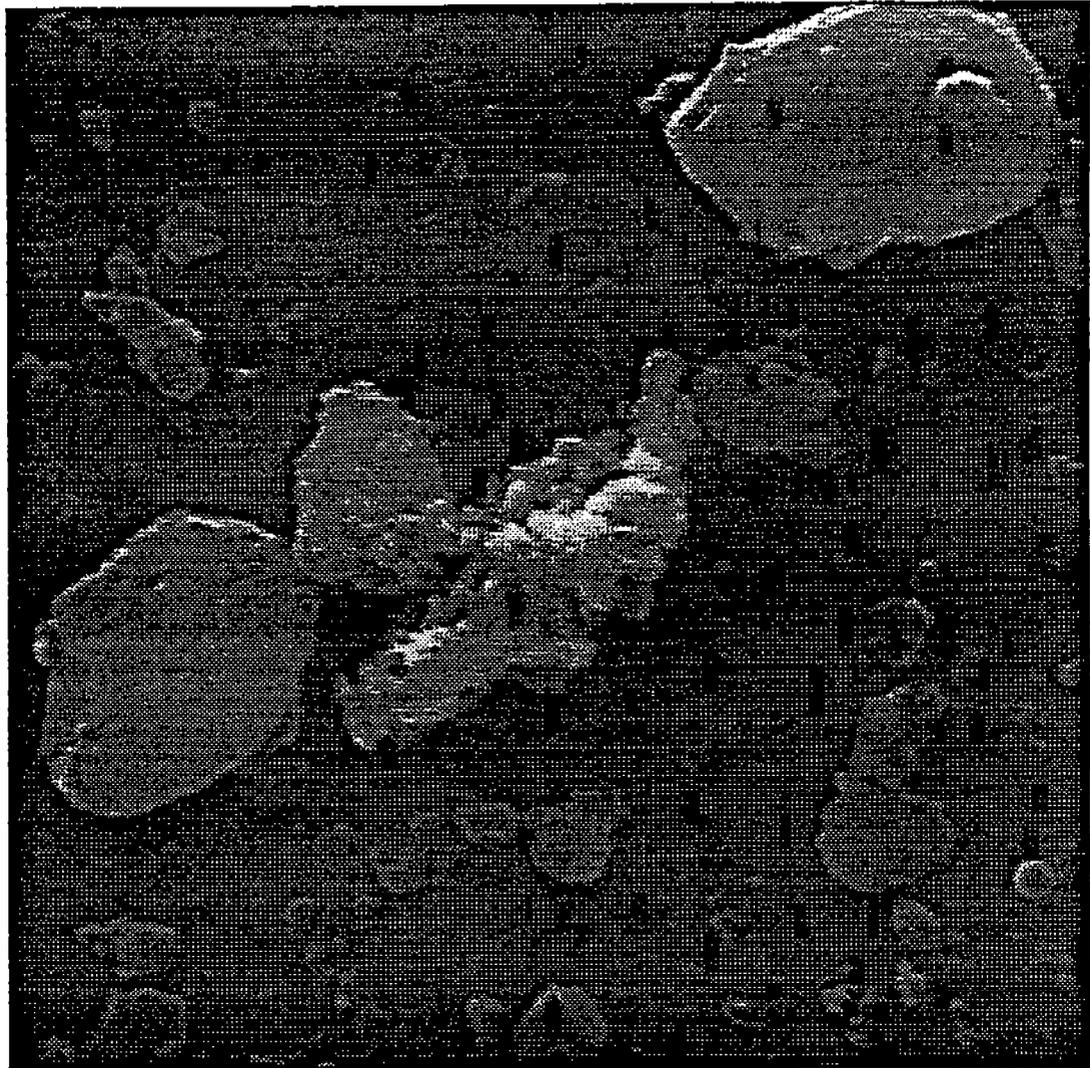


FIGURE 2



20 mm 20.0 keV 0.0 pA 5000- 3 u m
000

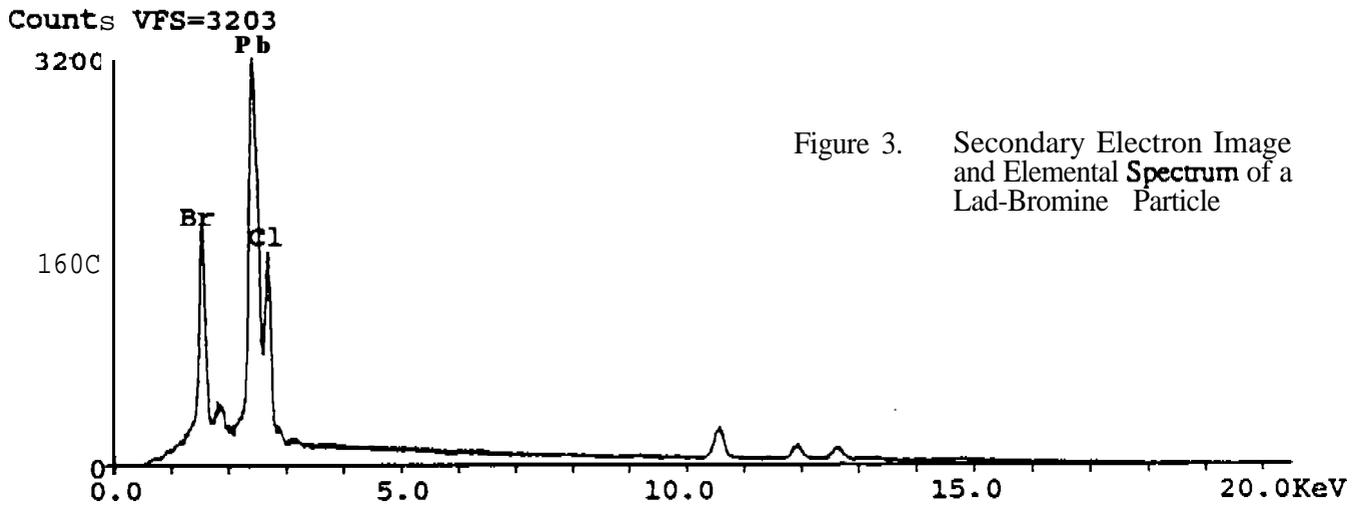
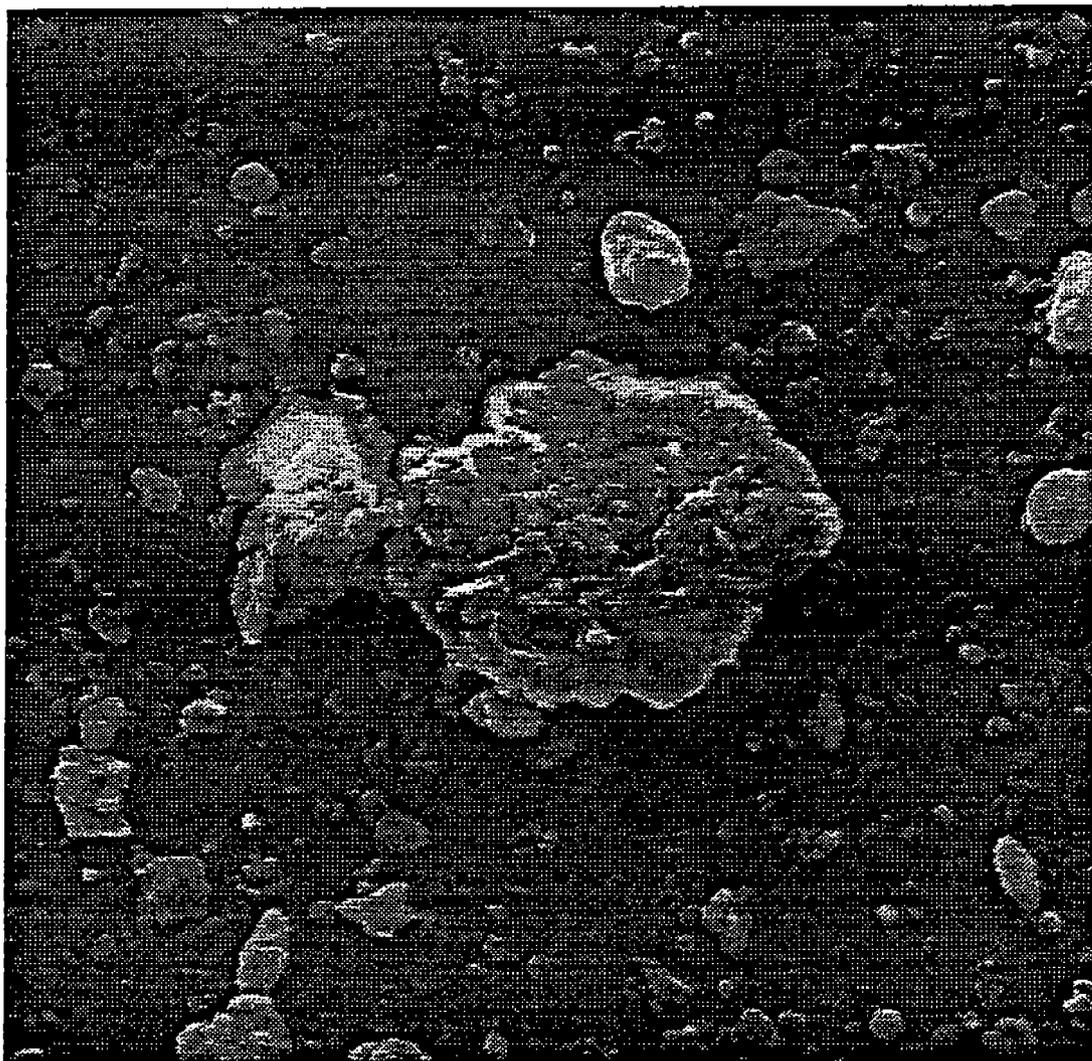


Figure 3. Secondary Electron Image and Elemental Spectrum of a Lead-Bromine Particle



20 mm 20.0 keV 0.0 pA 2000x 8um

Counts VFS=2958

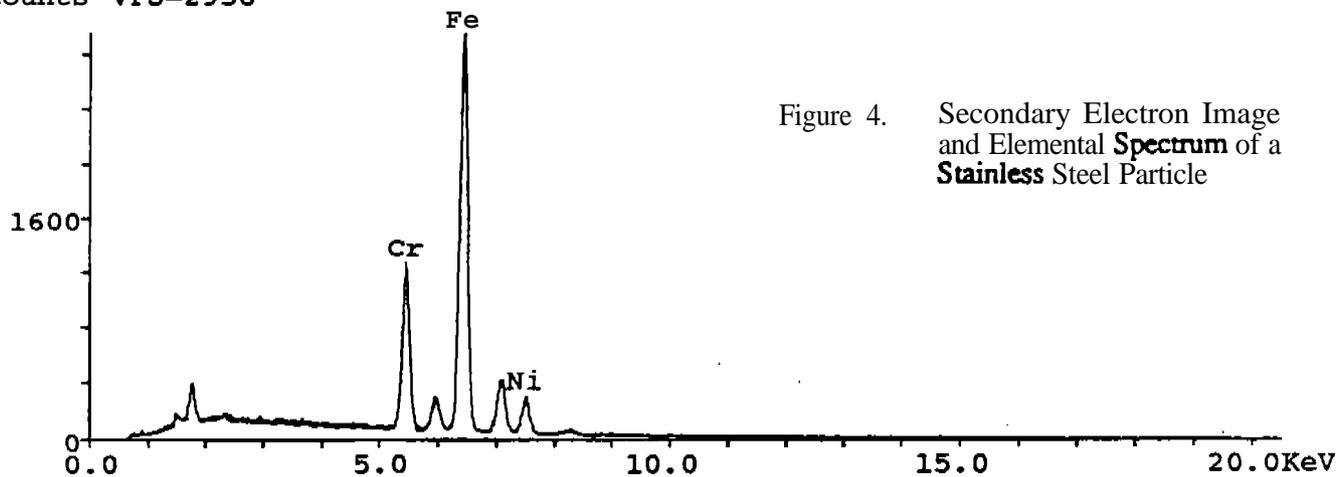
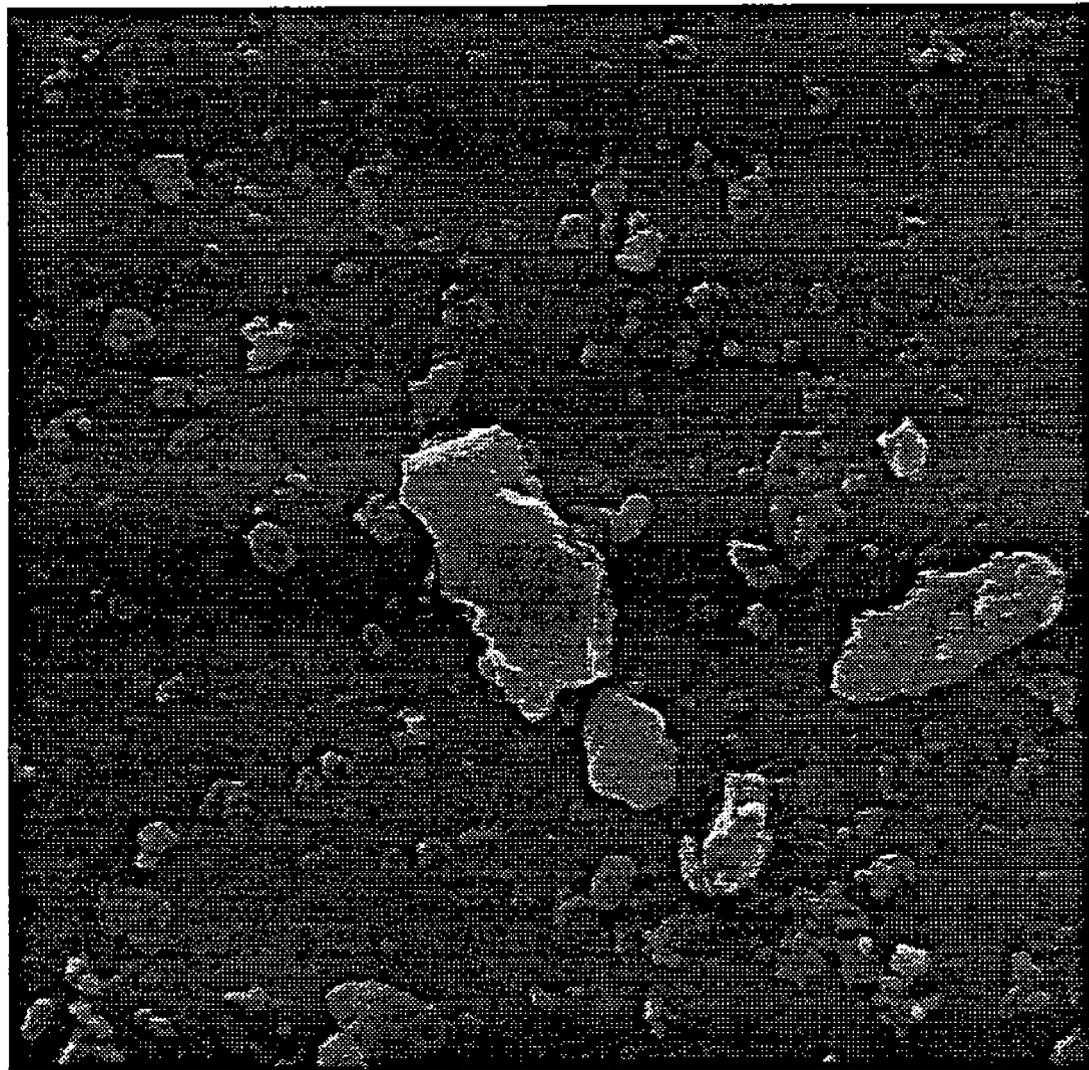


Figure 4. Secondary Electron Image and Elemental Spectrum of a Stainless Steel Particle



20 mm 20.0 keV 0.0 pA 3000x — 3um

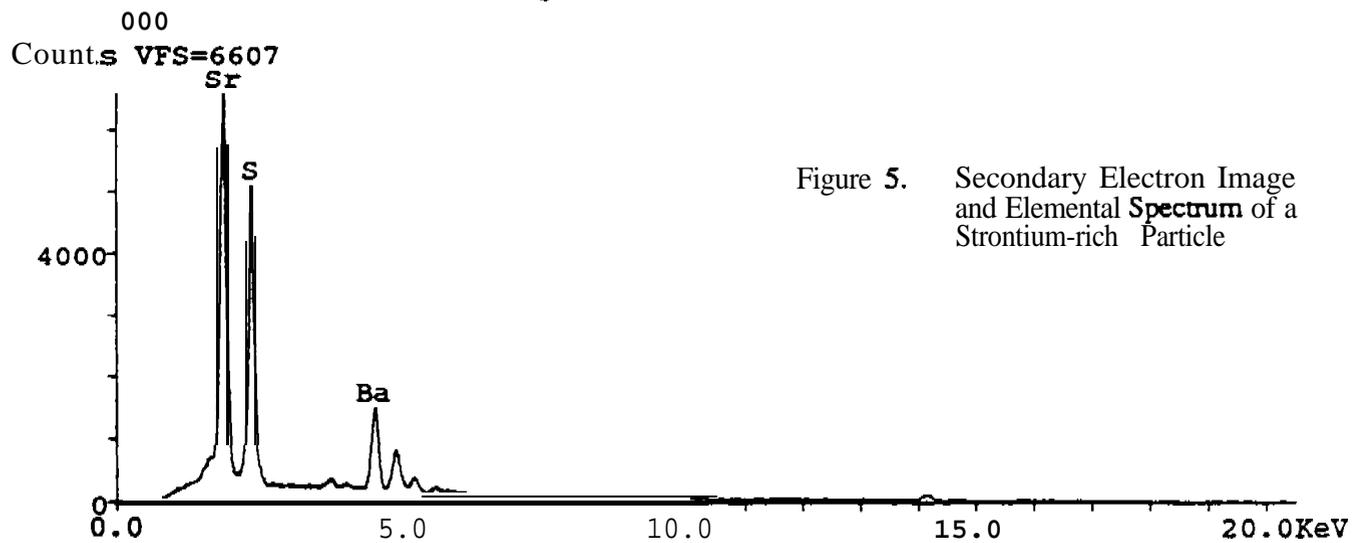
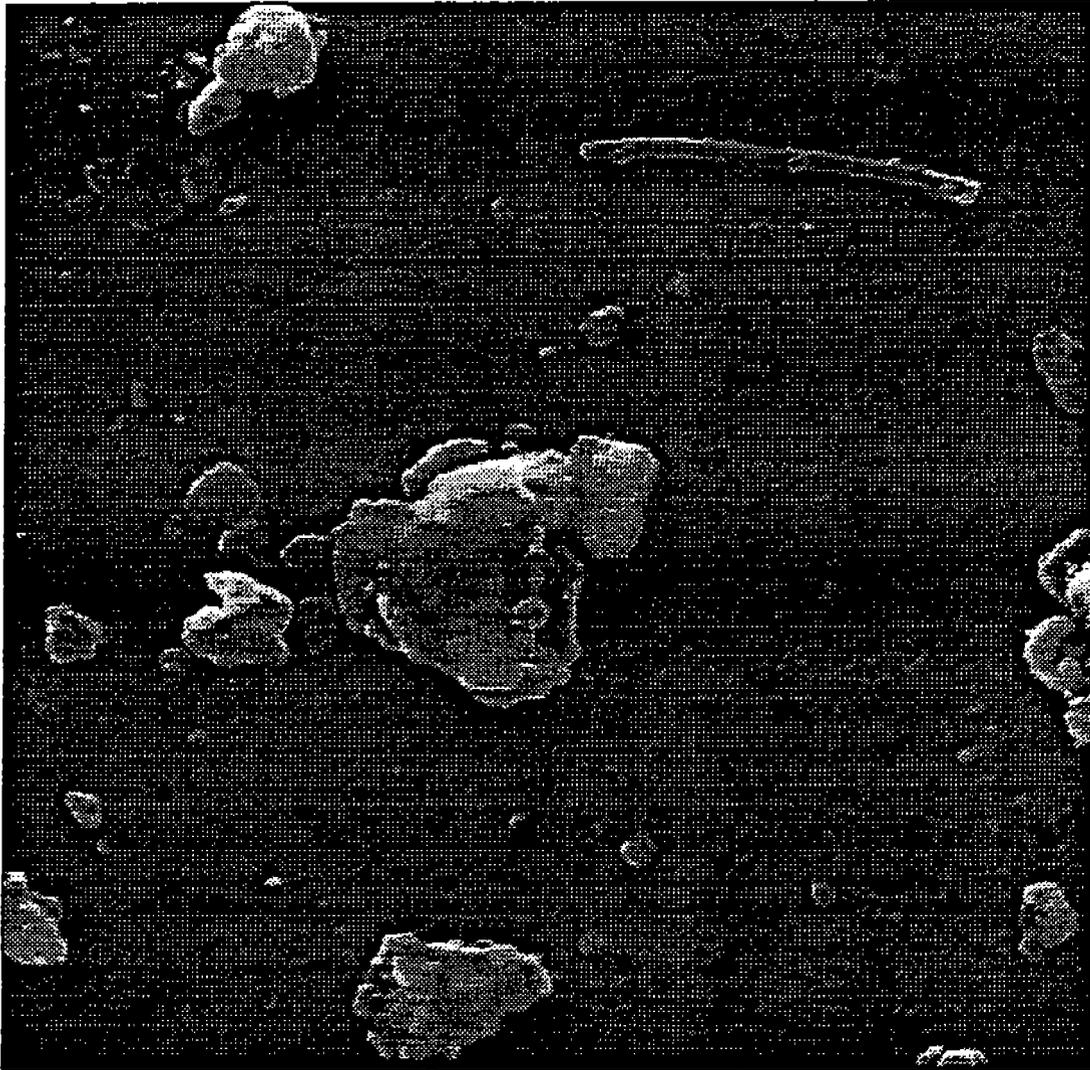


Figure 5. Secondary Electron Image and Elemental Spectrum of a Strontium-rich Particle



20 mm 20.0 keV 0.0 pA 3000x 3um

000

Counts VFS=3185

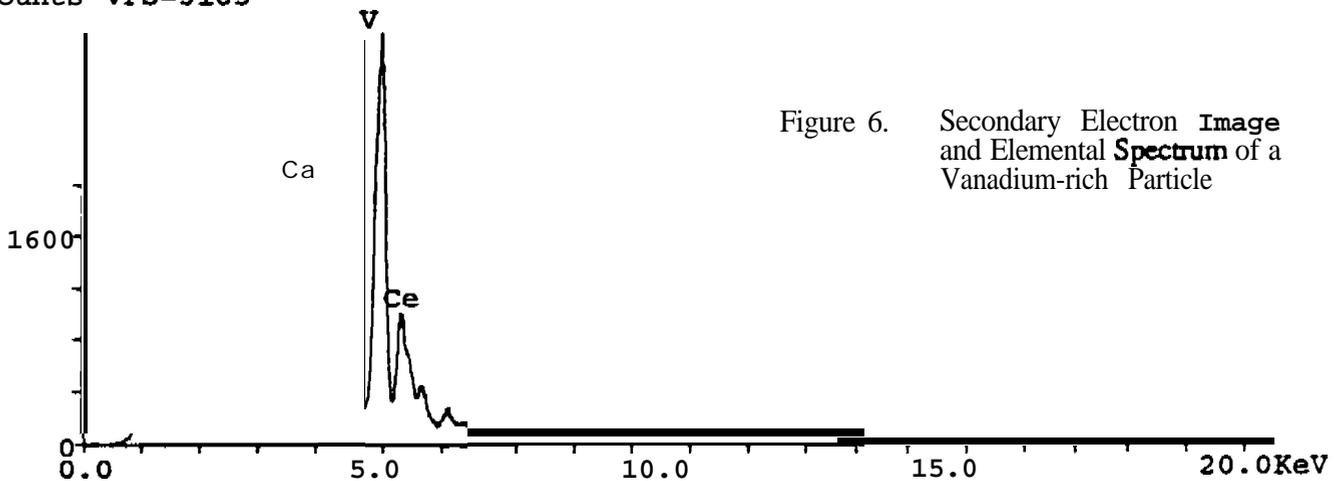


Figure 6. Secondary Electron Image and Elemental Spectrum of a Vanadium-rich Particle

a. Antimony, arsenic, **cadmium**, chromium, lead, nickel, strontium, vanadium and zinc were analyzed using a **Varian Model 300 GFAA**. Filters were prepared by the Occupational Safety and Health Administration (OSHA) Method ID-121 (Section 6.6). Briefly, filters were digested sequentially in fuming **nitric/perchloric acid**, **nitric/hydrofluoric acid**, and nitric acid followed by a final dilution to 10 mL at 4 percent nitric acid.

b. Antimony, arsenic, cadmium, nickel, strontium, vanadium, and zinc were found to be below the limits of quantitation on all samples. **Lead** levels above the background were detected in Samples **130-04, T136-04**, and 137-11. Elevated background levels of Cr and Zn were detected on the **filter** blank samples. Elevated background levels of chromium are not unexpected on **MCE filters**. Chromium levels on the order of 0.3 µg on new 37 mm MCE **filters** have been observed (reference 13).

TABLE G-13. ANALYTICAL METHODS USED FOR ELEMENTAL ANALYSES OF INDUSTRIAL HYGIENE SAMPLES

Element	Method	Instrumentation	Limit of Quantitation*
Arsenic	EPA SW846-7060	GFAA	5.0 ppb
Bromine	NIOSH 7903	IC	0.6 ppm
Cadmium	EPA SW846-7131	GF AA	5.0 ppb
Chromium	EPA SW846-7191	GFAA	5.0 ppb
Mercury	EPA SW846-7471A	CVAA	0.5 ppb
Nickel	EPA SW846-7520	GFAA	5.0 ppb
Lead	EPA SW846-7421	GFAA	5.0 ppb
Antimony	EPA SW8467041	GFAA	50.0 ppb
Strontium	EPA SW846-3050/7000A	GFAA	5.0 ppb
Vanadium	EPA SW846-7911	GFAA	10.0 ppb
Zinc	EPA SW846-7951	GFAA	5.0 ppb
Zirconium	RJ Lee Group Method	ICP	5.0 ppb

* Limit in the **final extraction** solution

c. Zirconium was analyzed using a method developed by RJ **Lee** Group for analysis of extract solutions using an ultrasonic **nebulizer** with ICP (reference 2). A **Spectro Analytical** Model D ICP was monitored at a wavelength of 339.20 nm for these analyses. Zirconium was found to be below the limit of quantitation for all personal filters analyzed.

d. Samples listed in Table G-12 were analyzed for Br using IC techniques. The NIOSH Method 7903 was used for this analysis. Samples were prepared by extraction with carbonate/bicarbonate IC eluent. Extracts were analyzed on a Dionex Model 2120i Ion Chromatograph using an Ionpac AS4 separation column and a Micromembrane Anion suppressor column from Dionex. Bromine was found to be below the limit of quantitation for all personal filters analyzed.

e. Results for the metals and bromine are summarized in Table G-2-35 in Annex G-2.

f. Filters were analyzed for mercury by EPA Method 7471A. With this method, these samples were digested in nitric acid/sulfuric acid/potassium sulfate/potassium permanganate at 95 °C and analyzed by CVAA. To optimize these analyses, heavily loaded filters with a larger portion available for analysis were selected. These filters are identified in Table G-14. Mercury was found to be below the limit of quantitation for all industrial hygiene samples analyzed. Data for these samples are reported in Table G-2-36.

TABLE G-14. IDENTIFICATION OF INDUSTRIAL HYGIENE SAMPLES ANALYZED FOR MERCURY

USAEHA Field Sample No.	Filter Type	Date Collected	Sample Location Site	RJ Lee Group Sample No.
T127-11	PVC	7 May 1991	Khobar, Saudi Arabia	60374s
R133-17	PVC	13 May 1991	Camp Freedom, Kuwait	601425
T133-18	PVC	13 May 1991	Camp Freedom, Kuwait	601406
R134-21	PVC	14 May 1991	Camp Freedom, Kuwait	601427
R136-03	PVC	16 May 1991	Camp Freedom, Kuwait	601408
T139-11	PVC	19 May 1991	Camp Thunderrock, Kuwait	601410
R152-07	PVC	1 Jun 1991	Al-Jubayl, Saudi Arabia	603772
R157-08	PVC	6 Jun 1991	Burgan Oil Field, Kuwait	603783
R313-07	Teflon	NA	NA	603878
F314-08	GF	NA	NA	603876

g. The analytical method used for each element is shown in Table G-13. Sample concentrations were based on calibration curves generated from certified reference standards. Details of the methods used for particular elements are described in Volume II of this report.

2. Organic Analyses. Sixteen industrial hygiene samples were analyzed using either FTIR spectroscopy and/or GC/MS detection. Two of these samples were collected at the Burgan Oil Fields on 20 May 1991 and were included to provide "source" information on the

oil fire plumes. Due to their heavy loading, better analytical sensitivity could be obtained from these samples. A field blank of each type of filter (i.e., MCE, PVC, and PC) was analyzed. A list of filters analyzed by FTIR and/or GC/MS is shown in Table G-15.

a. Samples listed in Table G-15 were analyzed on a 1700 Series Perkin-Elmer FTIR in reflectance mode. In addition to interpretation of spectra by an experienced chemist, spectra were compared to a Perkin-Elmer data base and several printed indices. Although many of these filters had a dark black appearance, the levels of organic material based on the infrared absorption were at trace levels. While the levels were below the limit of quantitation, they were estimated to be on the order of 10 µg/filter. Aromatic, aliphatic, and oxidized organics, such as carboxylic acids were indicated in these spectra.

b. Nine samples were analyzed by GC/MS as listed in Table G-15. These filters were weighed and extracted with carbon disulfide by soaking overnight followed by sonication for approximately 2 minutes in an ultrasonic bath. The extracts were then filtered and analyzed. The GUMS analyses were performed on a Hewlett Packard Model 5890 Series 2 Gas Chromatograph with a Model 5971A Mass Selective Detector using a 30 meter RTX-1 column from Restek. Total ion current (TIC) or selected ion current (SIM) programmed for the target compound list in EPA Method SW846-8270 were used to monitor for organic compounds. Details of the methods are described in Volume II of this report.

(1) Except for sample 140-11, no peaks were detected in unconcentrated extracts using GC/MS methods. A chromatogram of the extract from sample 140-11 showed peaks which were identified by GUMS as a dioxane derivative, diphenylphthalate, and nono-methylphenylcyclopentasiloxane. Although these compounds were detected, the levels were determined to be below the limit of quantitation (i.e., <5 µg/filter).

(2) Phthalate esters are well known contaminants caused by the use of latex gloves and plastic products. The silicone material observed could be produced by heated silicone lubricants or by sealants used in the filter assembly. Therefore, the compounds observed could be contaminants from the collection and analysis methods.

(3) Based on the results of the initial GC/MS analyses, selected samples were concentrated by evaporation under a stream of nitrogen and reanalyzed. After a 100-fold concentration, the extract from Filter 136-04 was reanalyzed by GC/MS. Several peaks were observed corresponding to various phthalate esters. However, no other analytes could be identified using this analysis.

TABLE G-15. PERSONAL FILTERS ANALYZED BY ORGANIC ANALYSES

USAEHA Field Filter Sample No.	Filter Type	Date Collected	Sample Location Site	Sample No.	USAEHA Sample No.	RJ Lee Group Analysis Method
130-04	MCE	10 May 1991	Khobar , Saudi Arabia	Y1109	601456	FTIR, GC/MS
130-10	MCE	10 May 1991	Khobar, Saudi Arabia	Y1112	603679	GC/MS
134-12	MCE	14 May 1991	camp Freedom, Kuwait	Y 1833	603684	FTIR
T134-20	PVC	14 May 1991	Camp Freedom, Kuwait	NA	601426	FTIR, GUMS
135-07	PVC	15 May 1991	Field Blank	NA	601429	FTIR, GC/MS
T136-04	PVC	16 May 1991	Camp Freedom , Kuwait	NA	601430	FTIR, GC/MS
137-I I	MCE	17 May 1991	Military Hospital , Kuwait	Y1836	601460	GC/MS
T140-05	PVC	20 May 1991	Burgan Oil Field, Kuwait	NA	601435	FTIR, GUMS
140-I I	MCE	20 May 1991	Burgan Oil Field, Kuwait	Y1837	600755	FTIR, GC/MS
R152-07	PVC	1 Jun 1991	Al-Jubayl , Saudi Arabia	NA	603772	FTIR
152-18	MCE	1 Jun 1991	Al-Jubayl , Saudi Arabia	Y3071	601448	FTIR
T155-15	PVC	4 Jun 1991	Al-Wafra, Kuwait	NA	603750	FTIR
OF/FB/31	PC	NA	Field Blank	25391	603707	GC/MS
OF/FB/58	PC	2 Nov 1991	Oil Fields, Kuwait	25393	603709	FTIR
R-3 13-07	Glass-fiber	NA	NA	NA	NA	FTIR
F-3 14-08	Teflon	NA	NA	NA	NA	FTIR

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c. Although the **FTIR** and **GC/MS** analyses performed on the **industrial** hygiene samples **indicated** that organic material was below the limit of quantitation, it should be noted that the samples were collected on filters using **personal** monitors. **As** such, most of the volatile organic material in the air was not trapped using this sampling technique. Other samples, collected using solid absorbents and **analyzed** by the **USAEHA**, are presented elsewhere in this document.

3. Particulate Composition and Sizing.

a. **MCB** Filter Samples. The **MCE** filter samples were collected in both Kuwait and Saudi **Arabia** between 10 May 1991 and 1 June 1991. Twenty-nine of the **filters** were sent to **RJ Lee** Group for evaluation. After **receipt**, the samples were given a **preliminary** optical **microscopy evaluation in order to gain some** insight on the condition of the individual filters and to assist with determining whether the particulate **loading** was **acceptable** for the **CCSEM/TEM** analysis. **Observations and** comments **recorded** at the time of sample receipt are presented in Tables G-2-37 through G-2-41 in Amex G-2. From this group, eight samples were chosen to be analyzed using a combination of CCSEM and **TEM** techniques. These samples were collected at Camp Freedom in Kuwait and **Khobar** and Al-Jubayl in Saudi Arabia. The CCSEM and **TEM** analyses provided information on individual particle size and composition which were used to construct particle size distribution data and particle type summaries.

(1) **Details on** the **preparation** and **analytical methods** used in this assessment are provided in Volume **II** of this report.

(2) Mass distribution results based on **aerodynamic** equivalent diameter @resented in Tables G-2-42 and G-2-43 in **Annex G-2)** **indicate** that the majority of particle mass for samples **collected** in all locations occurred in the size ranges less than 10 pm.

(3) **Particle type results** for this **group** of samples are presented in Tables **G-2-44** and **G-2-45**. These results **indicate** that the majority of particle mass associated **with** each sample location was **comprised** of **various** mixed clays, **silicon-rich** and **calcium-rich** mineral **types**. The samples were comprised primarily of **sand-based material**. Detailed review of **particle type data from the TEM analyses** of these filters **indicated** that the **majority** of particles **analyzed in this size range were CCA**. Sample **number** 133-14 revealed a higher percentage contribution by carbon-rich particle **types** than did the other **MCE** filter samples analyzed. Closer review of the CCSEM data from this sample **indicated** that two **large** ($> 10 \mu\text{m}$) carbon-rich particles were **detected during the analysis, thereby** influencing the overall mass contribution reported for the **carbon-rich types** on that sample.

(4) A subset of four **MCE** filters were analyzed manually in the SEM for the presence of particles containing heavy metals (i.e., higher atomic number constituents). The **filters** analyzed represented different locations in both Kuwait and Saudi Arabia. **Other** than lead-rich and **lead/bromine-rich features**, particles containing higher atomic number constituents **were** either not detected or detected only in limited numbers on the samples analyzed. No uranium particles were observed.

b. PVC Filter Samples. Samples were collected on PVC **filter** membranes in both Kuwait and Saudi Arabia between 7 May 1991 and 9 June 1991. Seventy-five of the **filters** were sent to **RJ Lee** Group for evaluation. After receipt, the samples were given a **preliminary optical** microscopy evaluation in order to **gain** some insight on the condition of the individual **filters** and to assist with determining whether the particulate loading was amenable for CCSEM analysis. Observations and comments **recorded** at the time of sample receipt are **presented** in Tables G-2-46 through G-2-56 in **Annex G-2**. From this group of samples, a total of 26 were chosen to **be** analyzed using **CCSEM** techniques. **Samples selected** for analysis were collected at **various** locations **in** Kuwait and Saudi Arabia. The CCSEM analyses provided information on individual particle size and composition which were used to construct particle mass distribution data and particle type **summaries**.

(1) Details on the **preparation** and analytical **methods** used in this assessment are provided in Volume **II** of this report.

(2) Mass distribution results based on **aerodynamic** equivalent diameter (presented in Tables G-2-57 and G-2-58 in Annex G-2) indicate that the majority of particle mass for most of these samples occurred in the size ranges less than about 10 μm . **Significant** differences **in** mass distribution results were observed with some sample sets collected at a common location but on **different** days.

(3) **Particle-type results** are presented in Tables G-2-59 and G-2-60 in Annex G-2. **These** results **indicate** that the majority of particle mass **associated** with each sample **from** this group was comprised of various **mixed** clays and silicon-rich mineral **types** along with calcium-rich **types**. This data **indicates** that the samples were comprised mainly of **sand-**based material. **Estimates** on the levels of CCA particles (i.e., particles less than 1 μm) could not be made due to interference with the filter matrix.

(4) A subset of six PVC **filters** were **analyzed** manually in the **SEM** for the presence of particles containing heavy metals (**i.e.**, higher atomic number **constituents**). The **filters** analyzed represented different locations **in** both Kuwait and Saudi Arabia. Other than **lead-**rich and **lead/bromine-rich features detected** on three of the six samples, particles containing higher atomic number constituents were either not **detected** or detected only in limited numbers on the samples analyzed. No **uranium** particles were observed.

c. PC Filter **Samples**. Samples were collected on PC filter membranes in both Kuwait and Saudi Arabia between 31 **October 1991** and 19 November 1991. Forty-five of the filters were sent to **RJ Lee** Group for evaluation. The PC samples **were** obtained because the **filter** substrate which is smooth was more amenable to the CCSEM analysis than samples **collected** on MCE or PVC filters. After **receipt**, the samples were given a preliminary optical microscopy evaluation in order to document the condition of the individual **filters** and to **assist** with determining whether the particulate loading was acceptable for CCSEM analysis. Observations and comments recorded at the time of sample receipt are presented in Tables G-2-61 through G-2-68 in Annex G-2. From this group of samples, 25 were chosen to be analyzed using a combination of CCSEM and **TEM** techniques. Samples selected for analysis were collected at various **locations** in Kuwait and Saudi **Arabia**. The CCSEM analyses provided **information** on individual particle size and composition which were used to construct particle size **distribution** data and **particle type** summaries.

(1) Details on the **preparation** and **analytical** methods used in **this** assessment are provided in Volume **II** of this report.

(2) Mass distribution results based on aerodynamic equivalent diameter (presented in Tables G-2-69 and G-2-70 in Annex G-2) **indicate** that the majority of particle mass for most of these samples **occurred** in the size ranges less than about 10 μm . However, a **significant** fraction of the particle mass was observed in the 10-30 μm size range for the samples. Significant differences in mass distribution results were observed with some sample sets collected at a common location but on different days.

(3) Particle-type results are presented in Tables G-2-71 and G-2-72 in Annex G-2. These results **indicate** that the majority of particle mass associated with each sample **from** this group was comprised of various mixed clays, silicon-rich and calcium-rich particle **types**. These data indicate that the particulate matter was composed mainly of sand-based material. Carbon-rich particles **also** accounted for a **significant** amount of the samples' mass. Review of the CCSEM and **TEM** data **indicated** that the majority of carbon-rich particulate mass on most samples from this **group** was contributed by those less than about 2.5 μm in diameter. Further **review** of the data revealed that the majority of **particles documented during** the **TEM** analysis of most samples were CCA.

(4) A subset of five PC **filters** were analyzed manually in the **SEM** for the presence of particles containing **heavy** metals (i.e., higher atomic number constituents). The **filters analyzed** represented different locations in **both Kuwait** and Saudi **Arabia**. Lead-rich and lead/bromine-rich particles were observed in higher abundance on two of the **samples** than on the others in this set. Other than this, particles containing higher atomic number constituents were either not **detected** or **detected only in** limited **numbers** on the samples **analyzed**. No **uranium** particles were observed.

V. CONCLUSIONS. Based on **sand** samples analysis, high-volume PM-10 samples and industrial hygiene samples, the salient **findings** of this assessment are:

A. Concentrations of Sb, **As**, Br, Cd, Cr, Pb, Hg, Ni, Sr, V, **Zn**, and **Zr** were determined to **be** at very low levels (i.e., **ng/m³**) at various locations **in** Kuwait and Saudi Arabia when the oil wells were **burning** (i.e., May 1991 to October 1991). In general, the levels of the metals were at higher levels in 1991 as compared to November 1993 data. This is illustrated in Figure 7 for **Zn**, Sr, V, Ni, Cr, Zn, and As in **ng/m³** for Khobar as a function of time. Figure 8 is the **same** representation for Camp **Thunderrock**. None of these metals were present above 400 **ng/m³** at these sites. **These** graphs show a decrease in the levels of **As**, Cr, Ni, Sr, V, **Zn**, and **Zr** with time after July 1991. **Lead** was not included on these graphs since there was **no** obvious trend with time for this metal.

B. Hexavalent chromium was determined to be below the **quantitation** level (i.e., **<5 ppb**) in **sand samples collected in Kuwait and Saudi Arabia**.

C. Hexavalent chromium was determined to **be** below the quantitation level (i.e., **<0.8 ng/m³**) in PM-10 samples.

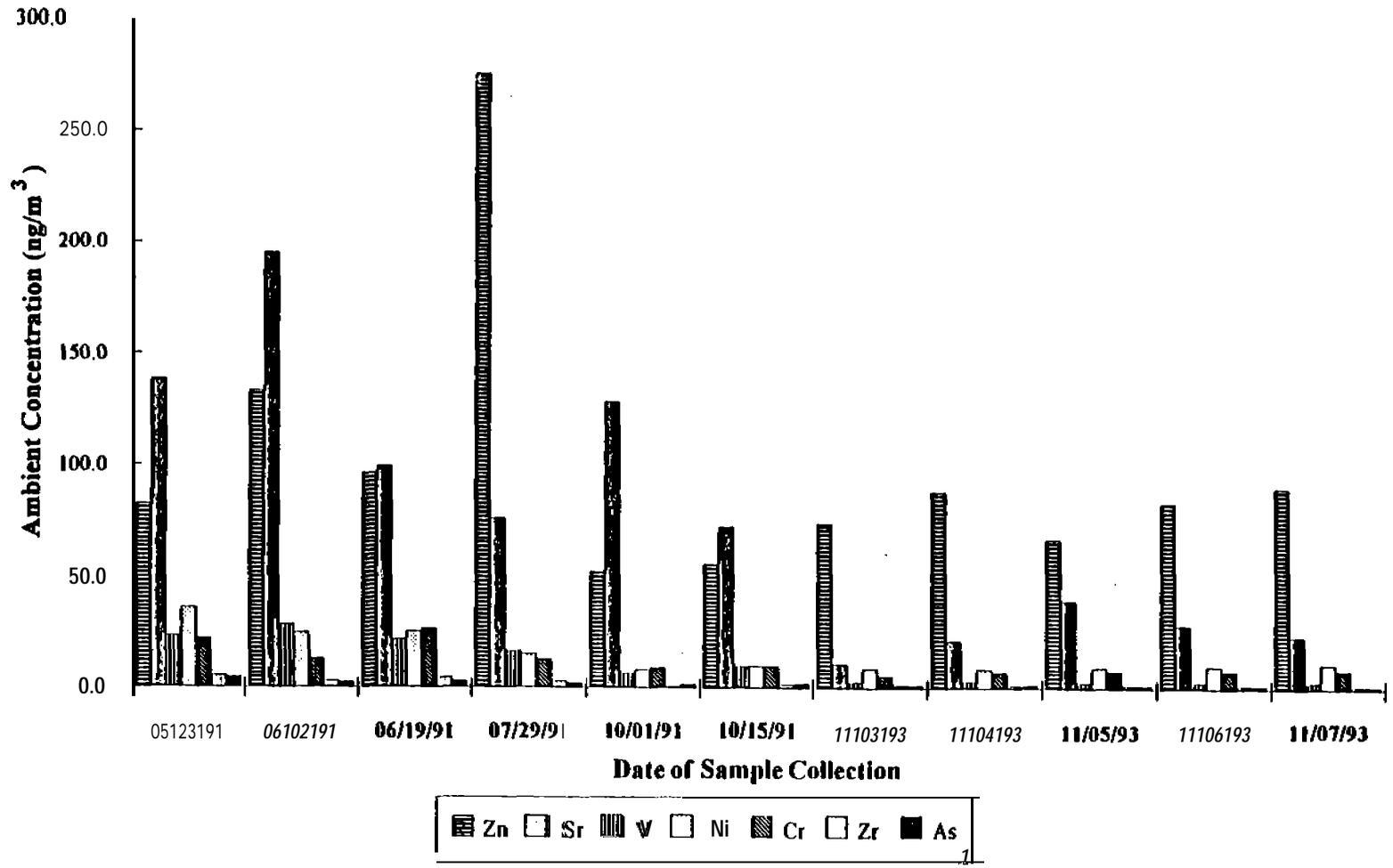
D. Elemental carbon data obtained from **thermal/optical** analysis indicate that **soot** from the oil **fire** plumes was, in general, only a minor component of the PM-10 mass.

E. The **CCSEM/TEM** microscopic data **indicates** that CCA associated with the oil **fire** plumes were, **in** general, only a minor component of the overall PM-10 mass. The **TEM** data indicated that the CCA particles consisted of two distinct size ranges (i.e., "small" and "large"). The small **carbon-chain** agglomerate (**SCA**) **fraction was made up** of individual **spherical particles typically** less than 0.1 μm in **diameter**. The large **carbon-chain** agglomerate (**LCA**) fraction was composed of **spherical particles greater** than or equal to 0.25 μm in size.

F. The **thermal/optical** elemental **carbon** and **CCSEM/TEM CCA data were in good** agreement. Figures 9 and 10 **illustrate** the relationship of CCA and elemental carbon to PM-10 concentration at **Khobar** and Camp **Thunderrock**. The fact **that** the **thermal/optical** elemental carbon results **compared** well with the **CCSEM/TEM** CCA data provides credence to both **methods**.

G. The **CCSEM/TEM data indicate** that sand-based particles accounted for the majority of the particle mass on most samples.

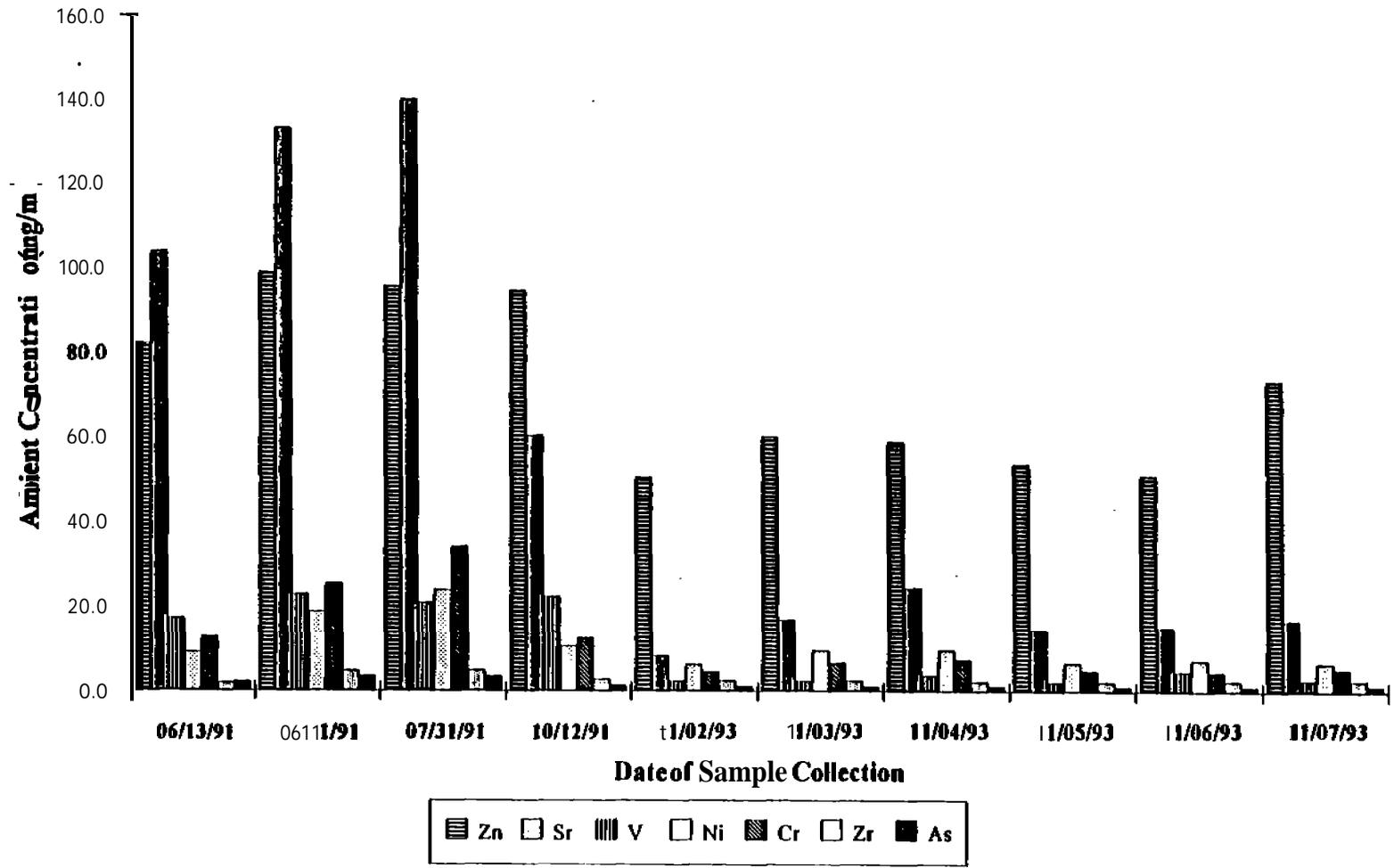
Elemental Analysis Results for PM-10 Samples Khobar, Saudi Arabia



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FIGURE 7

Elemental Analysis Results For PM-10 Samples
Camp Thundercrack, Kuwait



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FIGURE 8

Relationship of Soot to PM-10 Concentration

Khobar, Saudi Arabia

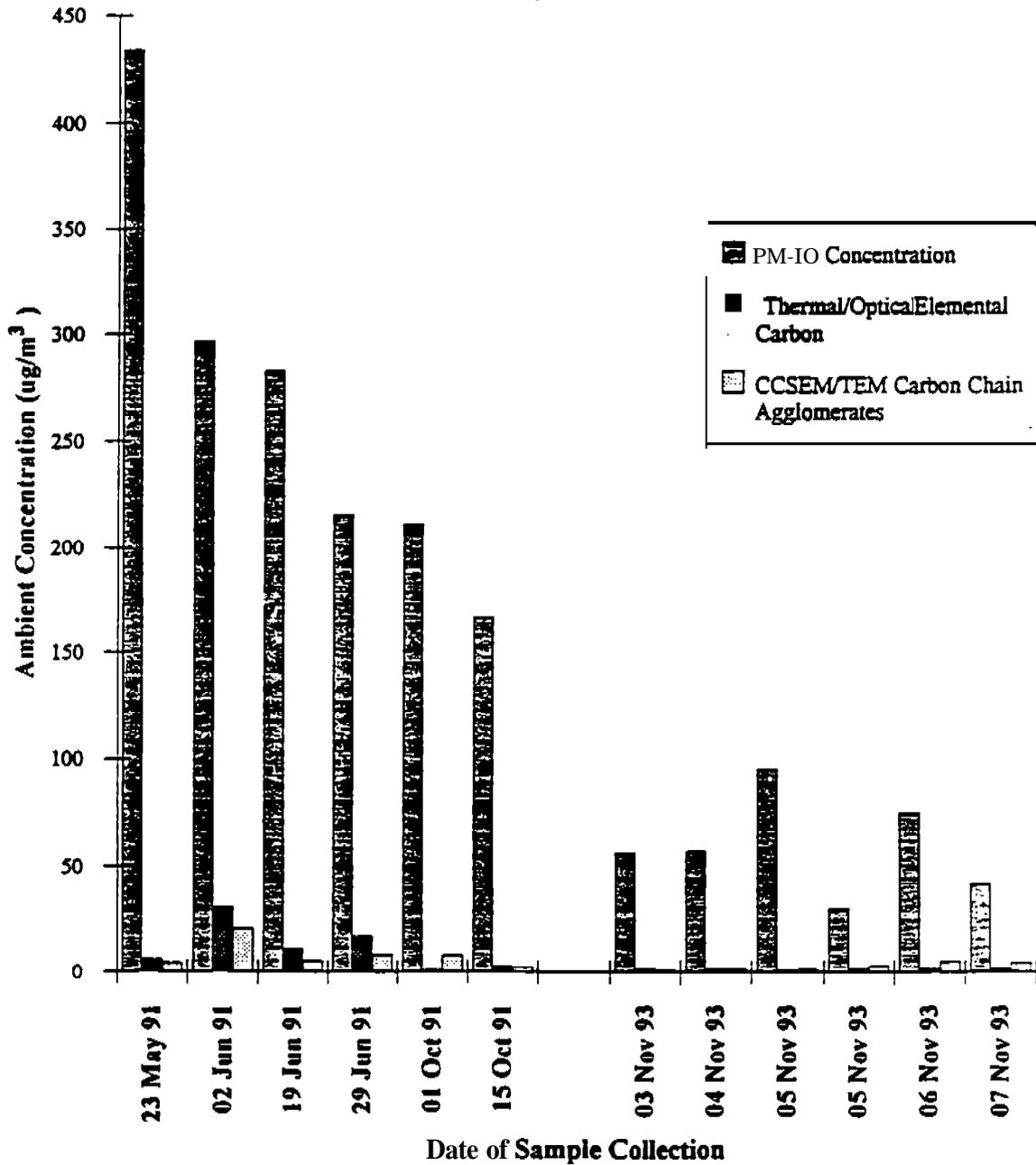


FIGURE 9

Relationship of Soot to PM-10 Concentration

Camp Thunderrock, Kuwait

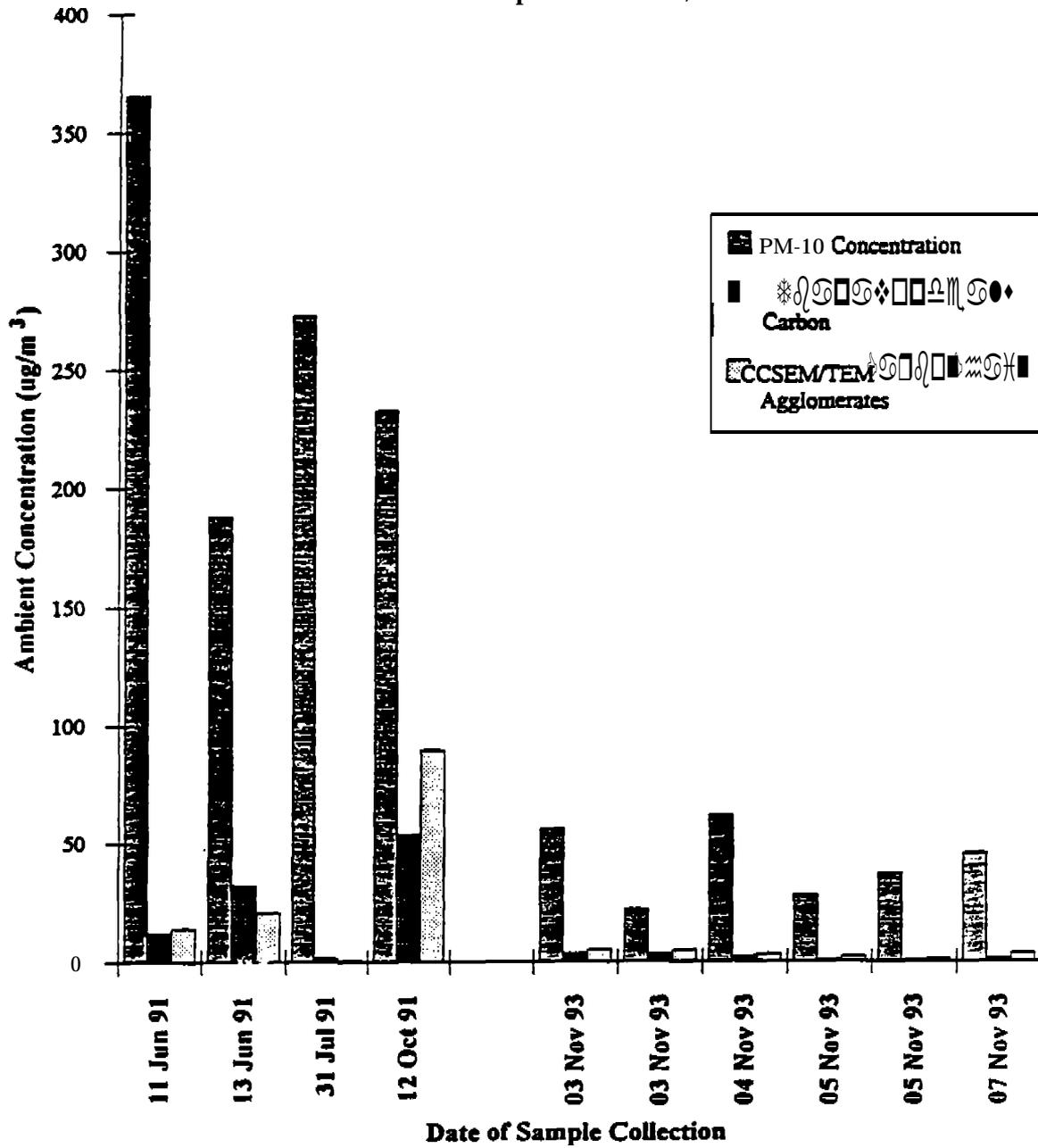


FIGURE 10

H. No uranium particles were detected using **CCSEM/TEM** technology. (It is estimated that over 4.0×10^7 particles were screened during the uranium evaluation.) Lead-bromide (automotive emissions) and stainless steel particles were detected in large numbers on some samples. Stainless steel particles were **also detected** on blank filters.

VI. **RECOMMENDATIONS.** Although the data reported in this assessment provide insight on ambient air quality in Kuwait and Saudi Arabia when the oil wells were on fire, it should be **realized** that the data set was **based** on a limited number of samples. Therefore, it is suggested that the following be considered:

A. To our knowledge, the **CCSEM/TEM** data is unique **because** it provides direct measurement on CCA particles. Since this particle **type** is used **as a tracer** of the oil fire plumes, the **CCSEM/TEM data can be used to estimate the impact from the oil well fires.** Through analysis of a larger **number** of samples and plotting the **data** with respect to location and meteorology, a **better estimate** of the **impact** of the oil well fires on ambient air quality in Kuwait and Saudi Arabia can be made. Therefore, it is recommended that **thermal/optical** and **CCSEM/TEM** analysis be performed on a **larger** set of PM-10 samples.

1. Thermal/optical analysis of additional PM-10 samples **can** be used to screen for additional samples for **CCSEM/TEM** analysis.

2. The **CCSEM/TEM** analysis **can be** performed on a subset of samples based on the **thermal/optical** analysis.

B. To date, only samples **collected** during and after the oil well fires have been analyzed. **Efforts** should **be** expanded to obtain samples which were collected before the oil fires. These additional data **can** be used to provide **better** estimates on ambient air quality **in** Kuwait and Saudi Arabia. This data set would **be especially** useful in ascertaining the levels of CCA particles in the atmosphere prior to the oil fires.

C. **In anticipation of** future **potentially catastrophic environmental** events, **USAEHA** in conjunction with other **governmental organizations** (e.g., EPA, NASA, **NIST**, NCAR, and NOAA) and universities should consider developing and implementing a comprehensive incident **response** program based on the experience gained **from** this current work- The **plan** could cover everything from how to identify the needed response to getting equipment and supplies in place **on short notices.**



ANNEX G-1

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ANNEX G-2
DATA TABLES

TABLE O-2-1. METALS AND BROMINE RESULTS FOR SANDSAMPLERCOLLECTEDIN 1993, µg/g

Sample Location Site	AEHA Sample Identification	RJ Lee Group Sample No.	V	Cr	Ni	Zn	Sr	Zr	Cd	As	Pb	Sb	Br	Hg
Camp Thunderrock	Big CT	605192	13.6	18.3	16.6	27.6	2255.3	0.9	<0.3	3.3	1.6	<2.5	<30.0	co.02
US Embassy	Big EM	605194	8.1	16.3	2.9	49.6	1109.9	0.7	co.2	1.2	11.0	<2.5	<30.0	<0.04
Al-Dhahran	Big DA	605 193	3.4	5.6	10.8	26.8	246.2	0.4	<0.2	0.7	1.2	<1.5	<30.0	co.03
Camp Freedom	Big CF	605191	7.1	19.3	...	22.9	103.0	1.1	<0.2	1.5	11.0	<2.4	<30.0	<0.01
Ahmadi Hosp.	Big AH	605189	16.7	24.8	11.8	30.5	121.3	1.3	<0.2	3.0	16.2	<2.5	<30.0	<0.05
Military Hosp.	Big MH	605195	9.4	8.9	13.5	19.6	145.5	0.9	<0.2	2.6	2.2	<2.5	<30.0	<0.01
Al-Jubayl	Big AJ	605190	9.5		8.3		293.4	0.9	<0.2	1.6	18.6	<2.5	<30.0	<0.02
Al-Jubayl	AJ Composite	605063	9.2	18.5	9.4	42.3 44.9	255.9	0.8	<0.2	1.8	11.9	<2.5	<30.0	<0.05

G-2-2

TABLE G-Z-2 IDENTIFICATION OF CARTRIDGES COLLECTED IN KUWAIT ANALYZED FOR WATER EXTRACTABLE HEXAVALENT CHROMIUM

AEHA Field Sample No.	Date Collected	AEHA Sample Identification	Sample Location Site	RJ Lee Group Sample No.
0001-C	2 Nov 1993	CT11-1	Camp Thunderrock	605128
0002-C	2 Nov 1993	CT13	Camp Thunderrock	605134
0003-C	2 Nov 1993	CT11-2	Camp Thunderrock	605129
0004-C	2 Nov 1993	CT11-3	Camp Thunderrock	605130
0005-C	2 Nov 1993	CT11-4	Camp Thunderrock	605131
0006-C	2 Nov 1993	CT12	Camp Thunderrock	605133
0007-C	2 Nov 1993	CT13 (6-12)	Camp Thunderrock	605136
0008-C	2 Nov 1993	CT11-5	Camp Thunderrock	605 132
0009-C	2 Nov 1993	CT Composite (Big Doha)	Camp Thunderrock	605126
0010-C	2 Nov 1993	CT13 (1-2)	Camp Thunderrock	605182
0011-C	2 Nov 1993	CT15	camp Thunderrock	605139
0012-C	2 Nov 1993	CT11	Camp Thunderrock	605127
0016-C	2 Nov 1993	CT14	Camp Thunderrock	605138
0017-C	2 Nov 1993	CT13 (0-6)	Camp Thunderrock	605135
0018-C	2 Nov 1993	c n 3 (2-3)	Camp Thunderrock	605137
0068-C	2 Nov 1993	Spike B CT (Big Doha)	Camp Thunderrock	605140
0013-C	3 Nov 1993	Spike A Embassy Comp	US Embassy	605 180
0014-C	3 Nov 1993	Embassy Comp. (Big M)	US Embassy	605 167
0015-C	3 Nov 1993	EM1 1 Surface cwp (0-6)	US Embassy	605168
0019-C	3 Nov 1993	EM12 Surface Composite	us Embassy	6005170
0020-C	3 Nov 1993	EM13 (0-6) Composite	us Embassy	605172
0062-C	3 Nov 1993	EM13 (6-12 Composite)	us Embassy	605173
0064-C	3 Nov 1993	EM13 (1-2 Composite)	us Embassy	6 0 5 1 7 4
0065-C	3 Nov 1993	EM13 (2-3 Composite)	US Embassy	60s 175
0067-C	3 Nov 1993	EM14 Surface composite	us Embassy	605 178
0069-C	3 Nov 1993	EM11-1 Surface (0-6)	US Embassy	6005169
0071-C	3 Nov 1993	EM12-1 Surface (0-6)	us Embassy	605171
0072-C	3 Nov 1993	EM13-1 Surface (0-6)	us Embassy	605176
0073-C	3 Nov 1993	EM13-2 Surface (0-6)	us Embassy	605177
0074-C	3 Nov 1993	EM14-1 Surface (0-6)	us Embassy	605179
0021-C	4 Nov 1993	AH Comp. (Big Ahmadi)	Ahmadi Hospital	605059
0022-C	4 Nov 1993	Spike C AH Comp. (Big AH)	Ahmadi Hospital	605062
0023-C	4 Nov 1993	AH12 Ahmadi Surf. Comp.	Ahmadi Hospital	605060
0024-C	4 Nov 1993	AH13 Surface Composite	Ahmadi Hospital	605061
0025-C	4 Nov 1993	CF Composite (Big CF)	Camp Freedom	605088
0026-C	4 Nov 1993	Spike D-CF Comp. (Big CF)	Camp Freedom	605092
0027-C	4 Nov 1993	CF1 1 Surface Composite	Camp Freedom	605089
0028-C	4 Nov 1993	CF12 Surface Composite	Camp Freedom	605090
0029-C	4 Nov 1993	CF13 Surface Composite	Camp Freedom	605091
0030-C	4 Nov 1993	MH Composite (Big MH)	Military Hospital	605 149
0031-C	4 Nov 1993	Spike E (Big MH)	Military Hospital	605153
0032-c	4 Nov 1993	MH1 1 Surface Composite	Military Hospital	605150
0033-C	4 Nov 1993	MH12 Surface Composite	Military Hospital	605151
0034-C	4 Nov 1993	MH13 Surface Composite	Military Hospital	605152

TABLE G-2-3. IDENTIFICATION OF CARTRIDGES COLLECTED IN SAUDI ARABIA ANALYZED FOR WATER EXTRACTABLE HEXA VALENT CHROMIUM

AEHA Field Sample No.	Date Collected	AEHA Sample Identification	Sample Location Site	RJ Lee Group Sample No.
0035-C	6 Nov 1993	DA Dhahran Composite (Big DA)	Al-Dhahran	605102
0036-C	6 Nov 1993	Spike F-Bin DA Composite	Al-Dhahran	605111
0037-C	6 Nw 1993	DA1 1 Surface Composite	Al-Dhahran	605103
0038-C	6 Nw 1993	DA11 (0-6) Composite	Al-Dhahran	605104
0039-C	6 Nw 1993	DA11 (612) Composite	Al-Dhahran	605105
0040-C	6 Nw 1993	DA11 (1-2) Composite	Al-Dhahran	605106
0041-C	6 Nw 1993	DA11 (2-3) Composite	Al-Dhahran	605107
0042-C	6Nw 1993	DA12 Surface Composite	Al-Dhahran	605108
0043-C	6 Nw 1993	DA14 Surface Composite	Al-Dhahran	605109
0044-C	6 Nov 1993	DAIS Surface Composite	Al-Dhahran	605110
0045-C	7 Nov 1993	AJ Composite (Big AJ)	Al-Jubayl	605073
0046-C	7 Nov 1993	Spike G - Big AJ	Al-Jubayl	605083
0047-C	7 Nov 1993	AJ11 Surface Composite	Al-Jubayl	605075
0048-C	7 Nov 1993	AJ12 Surface Composite	Al-Jubayl	605076
0049-C	7 Nov 1993	AJ13 Surface Composite	Al-Jubayl	605077
0050-C	7 N w 1993	AJ14 Surface Composite	Al-Jubayl	605078
0051-C	7 Nov 1993	AJ14 (0-6)	Al-Jubayl	605079
0052-C	7 Nov 1993	AI14 (6-12)	Al-Jubayl	605074
0053-C	7 N w 1993	AJ14 (1-2)	Al-Jubayl	605080
0054-C	7 Nov 1993	AJ14 (2-3)	Al-Juhayl	605081
0055-C	7 Nov 1993	AI15 Surface Composite	Al-Jubayl	605082
0057-C	8 Nov 1993	EV Area Surface Comp.	Eskan Village	605143
0058-C	8 Nw 1993	ES15 Surface Composite	Eskan Village	605144

TABLE G-24. IDENTIFICATION OF SAND SAMPLES COLLECTED IN KUWAIT ANALYZED FOR WATER EXTRACTABLE CHROMIUM

AEHA Field sample No.	Date Collected	AEHA Sample Identification	sample Location Site	RJ Lee Group Sample No.
0001-S	2 Nov 1993	CT11-1	Camp Thunderrock	605114
0002-S	2 Nov 1993	CT13	Camp Thunderrock	605120
0003-S	2 Nov 1993	CT11-2	Camp Thunderrock	605115
0004-S	2 Nov 1993	CT11-3	C a m p -	605116
0005-S	2 Nov 1993	CT11-4	- P -	605117
0006-S	2 Nov 1993	c n 2	Camp Thunderrock	605119
0007-S	2 Nov 1993	CT13 (6-12)	Camp Thunderrock	605122
0008-S	2 Nov 1993	CT11-5	Camp Thunderrock	605118
0009-S	2 Nov 1993	CT Composite (Big Doha)	Camp Thunderrock	605112
0010-S	2 Nov 1993	CT13 (1-2)	Camp Thunderrock	605181
0011-s	2 Nov 1993	CT15	Camp Thunderrock	605125
0012-s	2 Nov 1993	CT11	Camp Thunderrock	605113
0016-S	2 Nov 1993	CT14	c a m p -	605124
0017-S	2 Nov 1993	CT13 (0-6)	- P -	605121
0018-S	2 Nov 1993	CT13 (2-3)	c a m p -	605123
0014-S	3 Nov 1993	Embassy Comp. (Big M)	us Embassy	605154
0015-S	3 Nov 1993	EM11 Surface Comp (0-6)	US Embassy	605155
0019-s	3 Nov 1993	EM12 Surface Composite	us Embassy	605157
0020-S	3 Nov 1993	EM13 (0-6) Composite	us Embassy	605159
0062-S	3 Nov 1993	EM13 (6-12 Composite)	us Embassy	605160
0064-S	3 Nov 1993	EM13 (1-2 Composite)	us Embassy	605161
0065-S	3 Nov 1993	EM13 (2-3 Composite)	us Embassy	605162
0067-S	3 Nov 1993	EM14 Surface Composite	us Embassy	605165
0069-s	3 Nov 1993	EM1 1-1 Surface (0-6)	us Embassy	605156
0071-s	3 Nov 1993	EM12-1 Surface (0-6)	us Embassy	605158
0072-S	3 Nov 1993	EM13-1 Surface (0-6)	US Embassy	605163
0073-S	3 Nov 1993	EM13-2 Surface (0-6)	US Embassy	605164
0074-S	3 Nov 1993	EM14-1 Surface (0-6)	us Embassy	605166
0021-S	4 Nov 1993	AH Comp. (Big Ahmadi)	Ahmadi Hospital	605056
0023-S	4 Nov 1993	AH12 Ahmadi surf. Comp.	Ahmadi Hospital	605057
0024-S	4 Nov 1993	AH13 Surface Composite	Ahmadi Hospital	605058
0025-S	4 Nov 1993	CF Composite (Big CF)	Camp Freedom	605084
0027-S	4 Nov 1993	CF11 Surface Composite	Camp Freedom	605085
0028-S	4 Nov 1993	CF12 Surface Composite	Camp Freedom	605086
0029-S	4 Nov 1993	CF13 Surface Composite	Camp Freedom	605087
0030-S	4 Nov 1993	MH Composite (Big MH)	Military Hospital	605145
0032-S	4 Nov 1993	MH11 Surface Composite	Military Hospital	605146
0033-s	4 Nov 1993	MH12 Surface Composite	Military Hospital	605147
0034-S	4 Nov 1993	MH13 Surface Composite	Military Hospital	605148

TABLE G-2-5. IDENTIFICATION OF SAND SAMPLES COLLECTED IN SAUDI ARABIA ANALYZED FOR WATER EXTRACTABLE CHROMIUM

AEHA Field Sample No.	Date Collected	AEHA Sample Identification	Sample Location Sk	RJ Lee Group Sample No.
0035-S	6 Nov 1993	DA Dhahran Composite (Big DA)	Al-Dhahran	605093
0037-s	6 N w 1993	DA1 1 Surface Composite	Al-Dhahran	605094
0038-S	6 Nov 1993	DA11 (0-6) Composite	Al-Dhahran	605095
0039-s	6 Nov 1993	DA1 1 (6-12) Composite	Al-Dhahran	605096
0040-S	6 Nov 1993	DA11 (1-2) Composite	Al-Dhahran	605097
0041-s	6 N w 1993	DA11 (2-3) Composite	Al-Dhahran	605098
0042-S	6 Nov 1993	DA12 Surface Composite	Al-Dhahran	605099
0043-s	6 N w 1993	DA14 Surface Composite	Al-Dhahran	605100
0044-S	6 Nov 1993	DA15 Surface Composite	Al-Dhahran	605101
0045-S	7 Nov 1993	AJ Composite (Big AJ)	Al-Jubayl	605063
0047-S	7 Nov 1993	AJ1 1 Surface Composite	Al-Jubayl	605065
0048-S	7 N w 1993	AJ12 Surface Composite	Al-Jubayl	605066
0049-S	7 Nov 1993	AJ13 Surface Composite	Al-Jubayl	605067
0050-S	7 N w X993	AJ14 Surface Composite	Al-Jubayl	605068
0051-S	7 N w 1993	AJ14 (0-6)	Al-Jubayl	605069
0052-S	7 N w 1993	AJ14 (612)	Al-Jubayl	605064
0053-s	7 Nov 1993	AI14 (1-2)	Al-Jubayl	605070
0054-S	7 Nov 1993	MI4 (2-3)	Al-Jubayl	605071
0055-S	7 Nov 1993	AJ15 Surface Composite	Al-Jubayl	605072
0057-S	8 Nov 1993	EV Area Surface Comp.	Eskan Village	605141
0058-S	8 Nov 1993	ES15 Surface Composite	Eskan Village	605142

TABLE G-26. WATER-EXTRACTABLE TOTAL AND HEXAVALENT CHROMIUM (Cr-VI) RESULTS FOR SAND SAMPLES COLLECTED FROM KUWAIT, ppb

AEHA Field Sample Nos. (Sand/Cartridge)	RJ Lee Group Sample Nos. (Sand/Cartridge)	AEHA Sample Identification	Total Cr* (Sand)	Cr-VI** (Cartridge)
0001-S/0001-C	605114/605128	CT11-1	<17.9	<5.0
0002-S/0002-C	605120/605134	CT13	<17.9	<5.0
0003-S/0003-C	605115/605129	CT11-2	<17.9	<5.0
0004-S/0004-C	605116/605130	CT11-3	<17.9	<5.0
0005-S/0005-C	605117/605131	CT11-4	<17.9	<5.0
0006-S/0006-C	605119/605133	CT12	<17.9	<5.0
0007-S/0007-C	605122/605136	CT13 (6-12)	c17.9	<5.0
0008-S/0008-C	605118/605132	CT11-5	<17.9	<5.0
0009-S/0009-C	605112/605126	CT Composite (Big Doha)	c17.9	<5.0
0010-S/0010-C	605181/605182	CT13 (1-2)	<17.9	<5.0
0011-S/0011-C	605125/605139	CT15	<17.9	<5.0
0012-S/0012-C	605113/605127	CT11	<17.9	<5.0
0016-S/0016-C	605124/605138	CT14	<17.9	<5.0
0017-S/0017-C	605121/605135	CT13 (0-6)	<17.9	<5.0
0018-S/0018-C	605123/605137	CT13 (2-3)	c17.9	<5.0
0014-S/0014-C	605154/605167	Embassy Comp. (Big M)	c17.9	<5.0
0015-S/0015-C	605155/605168	EM11 Surface Comp (0-6)	<17.9	<5.0
0019-S/0019-C	605157/605170	EM12 Surface Composite	<17.9	<5.0
0020-S/0020-C	605159/605172	EM13 (0-6) Composite	<17.9	<5.0
0062-S/0062-C	605160/605173	EM13 (6-12 Composite)	c17.9	<5.0
0064-S/0064-C	605161/605174	EM13 (1-2 Composite)	c17.9	<5.0
0065-S/0065-C	605162/605175	EM13 (2-3 Composite)	<17.9	<5.0
0067-S/0067-C	605165/605178	EM14 Surface Composite	<17.9	<5.0
0069-S/0069-C	605156/605169	EM11-1 Surface (0-6)	c17.9	<5.0
0071-S/0071-C	605158/605171	EM12-1 Surface (0-6)	<17.9	<5.0
0072-S/0072-C	605163/605176	EM13-1 Surface (0-6)	<17.9	<5.0
0073-S/0073-C	605164/605177	EM13-2 Surface (0-6)	<17.9	<5.0
0074-S/0074-C	605166/605179	EM14-1 Surface (0-6)	c17.9	<5.0
0021-S/0021-C	605056/605059	AH Comp. (Big Ahmadi)	<17.9	<5.0
0023-S/0023-C	605057/605060	AH12 Ahmadi Surf. Comp.	<17.9	<5.0
0024-S/0024-C	605058/605061	AH13 Surface Composite	<17.9	<5.0
0025-S/0025-C	605084/605088	CF Composite (Big CF)	<17.9	<5.0
0027-S/0027-C	605085/605089	CF11 Surface Composite	c17.9	<5.0
0028-S/0028-C	605086/605090	CF12 Surface Composite	<17.9	<5.0
0029-S/0029-C	605087/605091	CF13 Surface Composite	<17.9	<5.0
0030-S/0030-C	605145/605149	MH Composite (Big MH)	c17.9	<5.0
0032-S/0032-C	605146/605150	MH11 (Surface Compos.)	c17.9	<5.0
0033-S/0033-C	605147/605151	MH12 Surface Composite	<17.9	<5.0
0034-S/0034-C	605148/605152	MH13 Surface Composite	<17.9	<5.0

* Total water-extractable chromium.

** Cr-VI in sand assuming a 20 g sample and all sample charged onto the cartridge.

TABLE G-Z-7.

RESULTS OF WATER-EXTRACTABLE TOTAL AND HEXAVALENT CHROMIUM (Cr-VI) ANALYSES ON SAND SAMPLES FROM SAUDI ARABIA, ppb

AEHA Field Sample No.	RJ Lee Group Sampk No.	AEHA sample Identification	Total Cr*	Cr-VI**
0035-S/0035-C	605102/605093	DA Dhahran Composite (Big DA)	c17.9	<5.0
0037-S/0037-C	605103/605094	DA1 1 Surface Composite	c17.9	<5.0
0038-S/0038-C	605104/605095	DA1 1 (0-6) Composite	<17.9	4.0
0039-S/0039-C	605105/605096	DA1 1 (6- 12) Composite	<17.9	4.0
0040-S/0040-C	605106/605097	DA11 (1-2) Composite	<17.9	4.0
0041-S/0041-C	605107/605098	DA1 1 (2-3) Composite	<17.9	<5.0
0042-S/0042-C	605108/605099	DA12 Surface Composite	<17.9	<5.0
0043-S/0043-C	605109/605100	DA14 Surface Composite	<17.9	<5.0
0044-S/0044-C	605110/605101	DA15 Surface Composite	<17.9	<5.0
0045-S/0045-C	605073/605063	AJ Composite (Big Al)	<17.9	<5.0
0047-S/0047-C	605075/605065	AJ11 Surface Composite	c17.9	<5.0
0048-S/0048-C	605076/605066	AJ12 Surface Composite	<17.9	<5.0
0049-S/0049-C	605077/605067	AJ13 Surface Composite	47.9	4.0
0050-S/0050-C	605078/605068	AJ14 Surface Composite	c17.9	4.0
0051-S/0051-C	605079/605069	AJ14 (0-6)	<17.9	4.0
0052-S/0052-C	605074/605064	All4 (6-12)	<17.9	<5.0
0053-S/0053-C	605080/605070	All4 (1-2)	<17.9	<5.0
0054-S/0054-C	605081/605071	AJ14 (2-3)	<17.9	4.0
0055-S/0055-C	605082/605072	AJ15 Surface Composite	<17.9	4.0
0057-S/0057-C	605143/605141	EV Area Surface Comp.	<17.9	<5.0
0058-S/0058-C	605144/605142	ES IS Surface Composite	<17.9	<5.0

* Total water-extractable chromium.

** Cr-VI in sand assuming a 20 g sample and all sample charged onto the cartridge.

TABLE G-2-S. RESULTS OF ANALYSIS OF CARTRIDGES FROM SAND SPIKED IN THE FIELD WITH HEXAVALENT CHROMIUM (Cr-VI)

RJ Lee Group		Cr-VI	Spike Level	% Spike
Sample No.	AEHA sample Identification	(ppb)	(ppb)	Recovery
605180	Spike A Embassy Composite	97.3	105.0	926%
605140	Spike B CT (Big Doha)	85.5	103.0	83.0%
605062	Spike C AH Composite. (Big AH)	155.7	106.0	146.8%
605092	Spike D CF Composite (Big CF)	180.7	115.0	157.1%
605153	Spike E (Big MH)	108.0	110.0	982%
605111	Spike F Big DA Composite	301.1	209.0	144.1%

TABLE G-2-9. SUMMARY OF CCSEM AERODYNAMIC MASS DISTRIBUTION RESULTS FOR SAND SAMPLES COLLECTED IN 1991, (WT.%)

AEHA Field Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	-----Particle Size Range (μm)-----				
				< 4	4-7.5	7.5-10	10-30	> 30
CF-5A	10 May 1991	Camp Freedom, Kuwait	601464	4	7	4	61	25
CF-6A	30 May 1991	Camp Freedom, Kuwait	601465	4	8	4	66	17
DA-4A	14 May 1991	Al-Dhahran, Saudi Arabia	601466	4	9	8	58	26
DA-IB-7	12 Sep 1991	Al-Dhahran, Saudi Arabia	601467				64	15
KK-4A	18 May 1991	KKMC, Saudi Arabia	601468	18	17	6	54	6

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TABLE G-2-10. SUMMARY OF CCSEM AERODYNAMIC MASS DISTRIBUTION RESULTS FOR SAND SAMPLES COLLECTED IN 1993, (WT. %)

AEHA Field Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	----- Particle Size Range (μm) -----				
				< 4	4-7.5	7.5-10	10-30	> 30
Big CT	3 Nov 1993	Camp Thunderrock, Kuwait	605192	3	5	5	26	61
Big EM	4 Nov 1993	US Embassy, Kuwait	605194	1	1	1		74
Big AH	5 Nov 1993	Ahmadi Hospital, Kuwait	605189	2	3	3	28	64
Big CF	5 Nov 1993	Camp Freedom, Kuwait	605191	5	4	3	33	55
Big MH	5 Nov 1993	Military Hospital, Kuwait	605195	3	3	2	60	32
Big DA	7 Nov 1993	Khobar, Saudi Arabia	605193	8	8	6		17
Big AJ	8 Nov 1993	Al-Jubayl, Saudi Arabia	605190	2	5	7	58	28
AJ Composite	8 Nov 1993	Al-Jubayl, Saudi Arabia	605063	2	3	4	61	30

TABLE G-2-11. SUMMARY OF CCSEM PARTICLE-TYPE DATA FOR SAND SAMPLES COLLECTED IN 1991

AEHA Field Sample No.	Collection Date	Sample Location Site	RJ Lee Group Sample No.	Si-rich and Mined Clays		C-e-rich		C-rich		Miscellaneous	
				wt. %	(# Part.)	Wt. %	(# Part.)	Wt. %	(# Part.)	wt. %	(# Part.)
CF-5A	10 May 1991	Camp Freedom, Kuwait	601464	62	158	34	96	3	42	< 1	3
CF-6A	30 May 1991	Camp Freedom, Kuwait	601465	17	60	40	86	27	108	15	45
DA-4A	14 May 1991	Al-Dhahran, Saudi Arabia	601466	30	52	70	163	9	60	4	9
DA-IB-7	12 Sep 1991	Al-Dhahran, Saudi Arabia	601467		111	67	152	2	16	t	20
KK-4A	18 May 1991	KKMC, Saudi Arabia	601468	50	168	43	100	5	23	2	8

TABLE G-2-12. SUMMARY OF CCSEM PARTICLE TYPE DATA RESULTS FOR SAND SAMPLES COLLECTED IN 1993

AEHA Field Sample No.	Collection Date	Sample Location Site	RJ Lee Group Sample No.	Si-rich and Mixed Clays		Ca-rich		C-rich		Miscellaneous	
				Wt. %	(# Part.)	Wt. %	(# Part.)	Wt. %	(# Part.)	wt. %	(# Part.)
Big CT	3 Nov 1993	CP Thunderrock, Kuwait	605192	45	101	50	143	2	84	3	10
Big EM	4 Nov 1993	US Embassy, Kuwait	605194	30	89	63		6	108	1	11
Big AH	5 Nov 1993	Ahmadi Hosp., Kuwait	605189	55	105	41	130	3	161	1	9
Big CF	5 Nov 1993	Camp Freedom, Kuwait	605191	38	82	35	to2	5	144	1	8
Big MH	5 Nov 1993	Military Hosp., Kuwait	605195		97	68	205 83	4	131	3	18
Big DA	7 Nov 1993	Khobar, Saudi Arabia	605193	60	53			2	76		11
Big AJ	8 Nov 1993	Al-Jubayl, Saudi Arabia	605190	17	35	67	136	13	161	3	15
AJ Composite	8 Nov 1993	Al-Jubayl, Saudi Arabia	605063	17	46	80	150	2	133	1	9

TABLE G-2-13. IDENTIFICATION OF PM-10 SAMPLES ANALYZED FOR METALS, BROMINE, AND HEXAVALENT CHROMIUM

AEHA Field Sample No.	Date Collected	Sample Location Site	PM-10 Conc. ($\mu\text{g}/\text{m}^3$)	RJ Lee Group Sample No.
5322375	2	May 1991 King Khalid Military City, Saudi Arabia	923.5	604999
5248123	26 Jul 1991	King Khalid Military City, Saudi Arabia	100.8	605002
5322339	23 May 1991	Khobar, Saudi Arabia	433.8	605003
5322318	2 Jun 1991	Khobar, Saudi Arabia	296.6	605004
5208839	19 Jun 1991	Khobar, Saudi Arabia	282.6	605005
5208619	29 Jul 1991	Khobar, Saudi Arabia	215.6	605006
K-27	1 Oct 1991	Khobar, Saudi Arabia	211.3	605007
K-40	15 Oct 1991	Khobar, Saudi Arabia	167.0	605008
01H2/3/AS/SD-6	3 Nov 1993	Khobar, Saudi Arabia	56.4	605033
01H2/3/AS/SD-7	4 Nov 1993	Khobar, Saudi Arabia	57.2	605034
01H2/3/AS/SD-9	4 Nov 1993	Khobar, Saudi Arabia	40.3	605035
01H2/3/AS/SD-11	5 Nov 1993	Khobar, Saudi Arabia	95.4	605036
01H2/3/AS/SD-13	5 Nov 1993	Khobar, Saudi Arabia	30.1	605037
01H2/3/AS/SD-14	6 Nov 1993	Khobar, Saudi Arabia	74.8	605038
01H2/3/AS/SD-16	6 Nov 1993	Khobar, Saudi Arabia	31.8	605039
01H2/3/AS/SD-17	7 Nov 1993	Khobar, Saudi Arabia	56.2	605040
01H2/3/AS/SD-18	7 Nov 1993	Khobar, Saudi Arabia	41.6	605041
01H2/3/AS/SD-20	7 Nov 1993	Khobar, Saudi Arabia	66.8	605042
5295163	20 Jun 1991	Eskan Village, Saudi Arabia	6975	605011
5207461	1 Aug 1991	Eskan Village, Saudi Arabia	115.3	605012
5322334	23 May 1991	Al-Jubayl, Saudi Arabia	338.7	605013
5332661	7 Jul 1991	Al-Jubayl, Saudi Arabia	337.9	605016
5208620	29 Jul 1991	Al-Jubayl, Saudi Arabia	175.1	605017
5334601	20 Jun 1991	Ahmadi Hospital, Kuwait	544.1	605019
5334638	26 Jun 1991	Ahmadi Hospital, Kuwait	191.0	605020
5339627	11 Jun 1991	Camp Thunderrock, Kuwait	365.7	605022
5339672	13 Jun 1991	Camp Thunderrock, Kuwait	188.0	605021
5208922	31 Jul 1991	Camp Thunderrock, Kuwait	272.4	605023
KA-18	12 Oct 1991	Camp Thunderrock, Kuwait	232.4	605024
X-H2/CT/AS/SD-43	2 Nov 1993	Camp Thunderrock, Kuwait	23.8	605043
X-H2/CT/AS/SD-45	3 Nov 1993	Camp Thunderrock, Kuwait	56.2	605044
X-H2/CT/AS/SD-46	3 NW 1993	Camp Thunderrock, Kuwait	55.3	605045
X-H2/CT/AS/SD-48	3 Nov 1993	Camp Thunderrock, Kuwait	27.8	605046
X-H2/CT/AS/SD-50	4 NW 1993	Camp Thunderrock, Kuwait	61.8	605047
X-H2/CT/AS/SD-52	4 Nov 1993	Camp Thunderrock, Kuwait	38.5	605048
X-H2/CT/AS/SD-53	5 Nov 1993	Camp Thunderrock, Kuwait	28.2	605049
X-H2/CT/AS/SD-55	5 Nov 1993	Camp Thunderrock, Kuwait	37.5	605050
X-H2/CT/AS/SD-56	6 Nov 1993	Camp Thunderrock, Kuwait	34.5	605051
X-H2/CT/AS/SD-58	6 Nov 1993	Camp Thunderrock, Kuwait	35.9	605052
X-H2/CT/AS/SD-60	6 Nov 1993	Camp Thunderrock, Kuwait	40.7	605053
X-H2/CT/AS/SD-61	7 Nov 1993	Camp Thunderrock, Kuwait	36.4	605054
X-H2/CT/AS/SD-62	7 Nov 1993	Camp Thunderrock, Kuwait	45.5	605055
5339613	20 May 1991	US Embassy, Kuwait	1105.7	605025
5248188	17 Jun 1991	us Embassy, Kuwait	612.7	605026
5334603	20 Jun 1991	us Embassy, Kuwait	293.5	605027
5295191	5 Jun 1991	Military Hospital, Kuwait	759.0	605028
5295153	17 Jun 1991	Military Hospital, Kuwait	610.8	605029
KA-17	12 Oct 1991	Military Hospital, Kuwait	121.6	605032

TABLE G-2-14. METALS AND BROMINE RESULTS FOR PM-10 SAMPLES COLLECTED IN KUWAIT (ng/m³)

AEHA Field Sample No.	Date Collected	RI Lee Group Sample No.	Sample Location Site	V	Cr	Ni	Zn	Sr	Zr	Cd	As	Pb	Sb	Br*	Hg
5334601	20 Jun 1991	605019	At-Ahmadi	40.5	22.5	24.8	a8.9	62.0	3	9	<1297	129.2	19.00	<0.7	1.2
5334638	26 Jun 1991	605020	Al-Ahmadi	16.3	13.4	10.4	65.5	84.3	2.6	<1.6	2.9	143.0	15.89	<0.6	0.4
5339613	20 May 1991	605025	US Embassy	46.0	73.0	46.7	104.9	168.0	8.0	<2.0	5.8	168.0	20.49	<0.7	0.7
5248188	17 Jun 1991	605026	US Embassy	32.7	73.9	53.7	82.4	198.3	8.6	<2.3	5.7	34.0	22.52	<0.8	0.7
53346133	20 Jun 1991	605027	US Embassy	24.5	25.3	18.5	97.4	110.3	<3.3	<3.3	<3.3	457.1	33.12	<1.1	2.0
5295 191	5 Jun 1991	605028	Military Hospital	31.0	70.5	51.0	78.0	162.1	7.1	ct.5	5.9	63.0	t5.00	<0.6	0.5
5295 153	17 Jun 1991	605029	Military Hospital	31.6	74.8	49.7	80.7	161.6	6.1	<2.2	5.8	40.5	22.16	<0.7	0.8
KA-17	12 Oct 1991	605032	Military Hospital	11.1	8.3	5.1	70.6	28.6	<1.5	<1.5	2.6	753.9	14.90	<0.4	1.4
5339627	11 Jun 1991	605022	Camp Thunderock	22.8	25.3	18.6	99.0	133.3	4.7	<2.7	3.6	29.6	26.91	<0.9	0.6
5339672	13 Jun 1991	605021	Camp Thunderock	17.1	12.8	9.1	82.2	103.9	1.9	1.7	2.2	32.5	16.12	<0.6	0.8
5208922	31 Jul 1991	605023	Camp Thunderock	20.8	34.1	23.7	95.8	140.0	4.8	<2.3	3.5	35.5	23.02	<0.9	0.7
KA-18	12 Oct 1991	605024	Camp Thunderock	22.2	12.7	10.6	94.9	60.3	<2.9	<2.9	<2.9	551.9	28.74	<0.7	0.8
X-H2/CT/AS/SD-43	2 Nov 1993	605043	Camp Thunderock	<4.9	4.6	6.2	50.7	8.4	<2.4	<2.4	<2.4	97.5	<24	<0.9	<0.7
X-H2/CT/AS/SD-45	3 Nov 1993	605044	Camp Thunderock	<5.4	7.6	11.7	75.1	20.0	<2.7	<2.7	<2.7	30.9	<27	<1.0	<0.8
X-H2/CT/AS/SD-46	3 Nov 1993	605045	Camp Thunderock	<4.9	7.7	10.4	62.7	20.8	<2.4	2.6	<2.4	31.0	<24	<0.9	<0.7
X-H2/CT/AS/SD-48	3 Nov 1993	605046	Camp Thunderock	<4.7	5.1	7.1	42.2	9.7	<2.3	<2.3	<2.3	24.1	<23	<0.8	<0.7
X-H2/CT/AS/SD-50	4 Nov 1993	605047	Camp Thunderock	5.0	8.11	12.5	66.4	32.1	<2.3	<2.3	2.3	26.5	<23	<0.8	<0.7
X-H2/CT/AS/SD-52	4 Nov 1993	605048	Camp Thunderock	<4.8	6.4	6.8	51.4	16.3	<2.4	<2.4	<2.4	18.6	<24	<0.9	<0.7
X-H2/CT/AS/SD-53	5 Nov 1993	605049	Camp Thunderock	<4.7	4.3	4.7	41.6	9.2	<2.4	<2.4	<2.4	24.0	<24	<0.9	<0.7
X-H2/CT/AS/SD-55	5 Nov 1993	605050	Camp Thunderock	<4.8	5.2	7.3	57.9	16.5	<2.4	<2.4	<2.4	23.1	<24	<0.9	<0.7
X-H2/CT/AS/SD-56	6 Nov 1993	605051	Camp Thunderock	5.6	5.1	10.3	60.2	13.4	<2.5	<2.5	<2.5	26.1	c 25	c o . 9	<0.7
X-H2/CT/AS/SD-58	6 Nov 1993	605052	Camp Thunderock	<5.1	4.1	5.7	46.7	15.0	2.6	<2.6	<2.6	23.7	<26	<0.9	<0.8
X-H2/CT/AS/SD-60	6 Nov 1993	605053	Camp Thunderock	5.9	4.8	6.0	46.4	16.8	<2.3	<2.3	<2.3	35.7	<23	<0.8	<0.7
X-H2/CT/AS/SD-61	7 Nov 1993	605054	Camp Thunderock	<5.7	5.5	6.6	78.6	17.4	<2.8	<2.8	<2.8	36.2	<28	<1.0	<0.8
X-H2/CT/AS/SD-62	7 Nov 1993	605055	Camp Thunderock	<5.4	4.9	6.6	68.4	16.1	<2.7	3.5	<2.7	52.5	<27	<1.0	<0.8

* Results for bromine reported as µg/m³

TABLE G-2-15. METALS AND BROMINE RESULTS FOR PM-10 SAMPLES COLLECTED IN SAUDI ARABIA (ng/m³)

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Sample Location	Site	V	Cr	Ni	Zn	Sr	Zr	Cd	As	Pb	Sb	Br*	Hg
5322375	22 May 1991	604999	KKMC		21.8	23.9	41.0	61.4	109.3	7.2	<1.4	3.5	8.5	<14	<0.7	0.6
5248123	26 Jul 1991	605002	KKMC		7.1	5.2	7.5	40.3	36.0	2.3	<1.1	1.5	22.7	<11	<0.4	1.3
5322334	23 May 1991	605013	Al-Jubayl		22.9	30.3	26.8	73.0	96.2	4.5	<1.4	3.4	111.2	14.26	<0.7	0.7
5332661	7 Jul 1991	605016	Al-Jubayl		23.9	24.9	24.9	54.9	84.8	3.5	<1.5	3.1	93.0	14.99	<0.3	0.6
5208620	29 Jul 1991	605017	At-Jubayt		15.1	15.2	12.5	55.8	45.9	3.6	<1.4	2.4	259.1	14.24	<0.5	0.8
5295163	20 Jun 1991	605011	Eskan Village		35.6	53.3	36.6	95.4	112.0	9.0	<1.6	5.2	136.7	15.90	<0.4	0.6
5207461	1 Aug 1991	605012	Eskan Village		7.9	12.3	6.7	74.1	29.2	2.9	<1.8	<1.8	42.5	17.72	<0.7	0.8
5322339	23 May 1991	605003	Khobar		23.6	22.4	36.4	82.5	138.1	5.4	<1.4	4.7	185.3	<14	<0.5	0.5
5322318	2 Jun 1991	605004	Khobar		28.9	13.4	24.9	133.1	195.3	3.0	<1.6	2.6	343.9	<16	<0.8	0.5
5208839	19 Jun 1991	605005	Khobar		22.0	26.7	25.4	96.5	99.3	4.3	cl.8	3.1	138.9	17.81	<0.9	0.4
5208619	29 Jul 1991	605006	Khobar		16.9	13.2	15.6	275.4	76.4	3.0	cl.2	2.2	317.4	11.93	<0.4	1.3
K-27	1 Oct 1991	605007	Khobar		6.9	9.3	8.5	52.6	128.6	<1.3	<1.3	1.7	56.4	13.43	<0.6	0.3
K-40	15 Oct 1991	605008	Khobar		10.0	10.3	10.2	56.2	72.8	1.7	<1.5	2.2	70.2	14.62	<0.5	0.2
01H2/3/AS/SD-6	3 Nov 1993	605033	Khobar		<5.8	5.3	9.2	74.2	11.1	<2.9	<2.9	<2.9	376.9	<29	ct.0	<0.9
01H2/3/AS/SD-7	4 Nov 1993	605034	Khobar		<6.4	8.2	9.9	96.5	26.3	<3.2	<3.2	<3.2	250.8	<32	<1.2	<1.0
01H2/3/AS/SD-9	4 Nov 1993	605035	Khobar		<5.9	6.1	8.0	79.2	17.1	<2.9	<2.9	<2.9	416.4	<29	<1.1	<0.9
01H2/3/AS/SD-11	5 Nov 1993	605036	Khobar		<6.0	7.6	10.4	75.4	71.6	<3.0	<3.0	<3.0	174.8	<30	<1.1	<0.9
01H2/3/AS/SD-13	5 Nov 1993	605037	Khobar		<5.7	7.8	8.8	58.8	8.3	<2.8	<2.8	<2.8	299.7	<28	<1.0	<0.8
01H2/3/AS/SD-14	6 Nov 1993	605038	Khobar		<6.3	8.4	11.2	86.9	45.6	<3.1	<3.1	<3.1	337.7	<31	<1.1	<0.9
01H2/3/AS/SD-16	6 Nov 1993	605039	Khobar		<5.5	7.7	9.5	79.3	11.4	<2.8	<2.8	<2.8	368.9	<28	<1.0	<0.8
01H2/3/AS/SD-17	7 Nov 1993	605040	Khobar		<5.8	8.6	12.2	80.3	27.1	<2.9	<2.9	<2.9	337.6	<29	<1.0	<0.9
01H2/3/AS/SD-18	7 Nov 1993	605041	Khobar		<5.5	8.6	10.1	82.9	12.6	<2.7	<2.7	<2.7	296.3	<27	<1.0	0.9
01H2/3/AS/SD-20	7 Nov 1993	605042	Khobar		<6.0	7.9	11.6	106.0	31.9	<3.0	<3.0	<3.0	238.3	<30	<1.1	<0.9

* Results for bromine reported as µg/m³

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TABLE G-2-16. RESULTS OF WATER-EXTRACTABLE TOTAL AND HEXAVALENT CHROMIUM (Cr-VI) ANALYSES FOR PM-10 FILTERS COLLECTED IN KUWAIT, ng/m³

AEHA Field Sample No.	RJ Loc Group Sample No.	Date Collected	Sample Location Site	Total Cr*	Cr-VI
5334601	605019	20 Jun 1991	Al-Ahmadi	cl.0	CO.5
5334638	605020	26 Jun 1991	Al-Ahlnadi	<0.8	<0.4
5339613	605025	20 May 1991	us Embassy	cl.1	<0.5
5248188	605026	17 Jun 1991	us Embassy	<8.0	<0.5
5334603	605027	20 Jun 1991	us Embassy	cl.9	<0.9
5295191	605028	5 Jun 1991	Military Hospital	<2.7	co.4
5295153	605029	17 Jun 1991	Military Hospital	Cl.1	<0.6
KA-17	605032	12 Oct 1991	Military Hospital	<0.7	co.4
5339621	605022	11 Jun 1991	Camp Thunderock	cl.4	<0.7
5339672	605021	13 Jun 1991	Camp Thunderock	co.9	<0.4
5208922	605023	31 Jul 1991	Camp Thunderock	<1.2	<0.6
KA-18	605024	12 Oct 1991	Camp Thunderock	<1.6	<0.8
X-H2/CT/AS/SD-43	605043	2 Nov 1993	Camp Thunderock	cl.3	co.7
X-H2/CT/AS/SD-45	605044	3 Nov 1993	Camp Thunderock	<1.4	co.7
X-H2/CT/AS/SD-46	605045	3 Nov 1993	Camp Thunderock	<1.3	<0.6
X-H2/CT/AS/SD-48	605046	3 Nov 1993	Camp Thunderock	cl.3	<0.6
X-H2/CT/AS/SD-50	605047	4 Nov 1993	Camp Thunderock	<1.2	<0.6
X-H2/CT/AS/SD-52	605048	4 Nov 1993	Camp Thunderock	cl.3	<0.6
X-H2/CT/AS/SD-53	605049	5 Nov 1993	Camp Thunderock	1.3	<0.6
X-H2/CT/AS/SD-55	605050	5 Nov 1993	Camp Thunderock	cl.3	<0.6
X-H2/CT/AS/SD-56	605051	6 Nov 1993	Camp Thunderock	cl.3	co.7
X-H2/CT/AS/SD-58	605052	6 Nov 1993	Camp Thunderock	cl.4	co.7
X-H2/CT/AS/SD-60	605053	6 Nov 1993	Camp Thunderock	cl.3	<0.6
X-H2/CT/AS/SD-61	605054	7 Nov 1993	Camp Thunderock	cl.5	CO.8
X-H2/CT/AS/SD-62	605055	7 Nov 1993	Camp Thunderock	cl.4	co.7

* Total water-extractable chromium

TABLE G-2-17. RESULTS OF WATER-EXTRACTABLE TOTAL AND HEXAVALENT CHROMIUM (Cr-VI) ANALYSES FOR PM-10 FILTERS COLLECTED IN SAUDI ARABIA, ng/m³

AEHA Field Sample No.	RJ Lee Group Sample No.	Date Collected	Sample Location Site	Total Cr*	Cr-VI
5322375	604999	22 May 1991	KKMC	c5.3	co.4
5248123	605002	26 Jul 1991	KKMC	<0.6	<0.3
5322334	605013	23 May 1991	Al Jubayl	<0.8	co.4
5332661	605016	7 Jul 1991	Al Jubayl	<0.8	<0.4
5208620	605017	29 Jul 1991	Al Jubayl	0.8	co.4
5295 163	605011	20 Jun 1991	Eskan Vil.	<0.8	co.4
5207461	605012	1 Aug 1991	Eskan Vil.	co.9	<0.5
5322339	605003	23 May 1991	Khobar	<0.8	<0.4
5322318	605004	2 Jun 1991	Khobar	<0.8	co.4
5208839	605005	19 Jun 1991	Khobar	<0.9	CO.5
5208619	605006	29 Jul 1991	Khobar	<0.6	CO.3
K-27	605007	1 Oct 1991	Khobar	co.7	<0.4
K-40	605008	1s Oct 1991	Khobar	CO.8	co.4
01H2/3/AS/SD-6	605033	3 Nov 1993	Khobar	4.0	<0.8
01H2/3/AS/SD-7	605034	4 Nov 1993	Khobar	<1.7	co.9
01H2/3/AS/SD-9	605035	4 Nov 1993	Khobar	<1.6	<0.8
01H2/3/AS/SD-11	605036	5 Nov 1993	Khobar	<1.6	<0.8
01H2/3/AS/SD-13	605037	5 Nov 1993	Khobar	<1.5	<0.8
01H2/3/AS/SD-14	605038	6 Nov 1993	Khobar	<1.7	CO.8
01H2/3/AS/SD-16	605039	6 Nov 1993	Khobar	c1.5	<0.7
01H2/3/AS/SD-17	605040	7 Nov 1993	Khobar	<1.6	<0.8
01H2/3/AS/SD-18	605041	7 Nov 1993	Khobar	Cl.5	<0.7
01H2/3/AS/SD-20	605042	7 Nov 1993	Khobar	<1.6	<0.8

* Total water-extractable chromium

TABLE O-2-18. IDENTIFICATION AND RESULTS ASSOCIATED WITH PM-10 SAMPLES SELECTED FOR THERMAL/OPTICAL ANALYSIS

Location	Date Collected	RJ Lee Group Sample No.	AEHA Lab No.	PM-10 Conc. ($\mu\text{g}/\text{m}^3$)	Organic Carbon ($\mu\text{g}/\text{m}^3$)	Elemental ($\mu\text{g}/\text{m}^3$)	Carbonate ($\mu\text{g}/\text{m}^3$)	Total Carbon ($\mu\text{g}/\text{m}^3$)
KKMC	26 Jul 1991	605002	Y8948	100.8	2.2 (2%)	1.8 (2%)	2.0 (2%)	6.0 (6%)
Khobar	23 May 1991	605003	Y2104	433.6	5.6 (1%)	6.2 (1%)	9.5 (2%)	21.3 (4%)
Khobar	2 Jun 1991	605004	Y3109	296.6	7.3 (2%)	30.6 (10%)	5.7 (2%)	43.6 (14%)
Khobar	19 Jun 1991	605005	Y4787	282.6	4.8 (2%)	11.0 (4%)	6.1 (2%)	21.9 (8%)
Khobar	29 Jul 1991	605006	Y8946	215.6	6.2 (3%)	17.4 (8%)	3.6 (2%)	27.2 (13%)
Khobar	1 Oct 1991	605007	23051	211.3	4.0 (2%)	0.9 (<1%)	3.6 (2%)	8.5 (4%)
Khobar	15 Oct 1991	605008	Z3713	167.0	6.2 (4%)	2.8 (2%)	1.1 (1%)	10.1 (7%)
Khobar	3 Nov 1993	605033	SD-6	56.4	3.3 (6%)	1.6 (3%)	0.0 (0%)	4.9 (9%)
Khobar	4 Nov 1993	605034	SD-7	57.2	3.3 (6%)	1.3 (2%)	1.3 (2%)	5.9 (10%)
Khobar	5 Nov 1993	605036	SD-II	95.4	4.2 (4%)	1.1 (1%)	4.1 (5%)	9.4 (10%)
Khobar	5 Nov 1993	605037	SD-13	30.1	3.5 (12%)	1.7 (6%)		5.2 (18%)
Khobar	6 Nov 1993	605038	SD.14	74.8	6.0 (8%)	1.8 (2%)	0.0 (0%)	9.9 (13%)
Khobar	7 Nov 1993	605041	SD-IS	41.6	4.6 (11%)	1.9 (4%)	0.0 (0%)	6.5 (15%)
Eskan Village	20 Jun 1991	605011	Y4769	697.5	20.0 (3%)	2.2 (<1%)	3.2 (<1%)	25.4 (3%)
Eskan Village	1 Aug 1991	605012	Y9826	115.3	18.2 (7%)	4.7 (4%)	0.7 (1%)	13.6 (12%)
Al-Jubayl	23 May 1991	605013	Y2101	338.7	6.3 (2%)	11.8 (3%)	8.8 (3%)	26.9 (8%)
Al-Jubayl	7 Jul 1991	605016	Y6482	337.9	6.8 (2%)	29.0 (9%)	a.3 (2%)	44.1 (13%)
Al-Jubayl	29 Jul 1991	605017	Y8947	175.1	4.6 (3%)	14.9 (9%)	2.9 (2%)	22.4 (14%)
Ahmadi Hospital	20 Jun 1991	605019	Y5148	544.1	39.0 (7%)	198.5 (36%)	5.5 (1%)	243.0 (44%)
Ahmadi Hospital	26 Jun 1991	605020	Y5642	191.0	3.0 (2%)	7.8 (4%)	0.0 (0%)	10.8 (6%)
Camp Thunderrock	13 Jun 1993	605021	Y4401	188.0	7.5 (4%)	32.4 (17%)	2.8 (2%)	41.9 (23%)
Camp Thunderrock	11 Jun 1991	605022	Y4469	365.7	8.1 (2%)	12.2 (3%)	7.0 (2%)	27.3 (7%)
Camp Thunderrock	31 Jul 1991	605023	Y9110	272.4	6.1 (2%)	1.7 (1%)	3.5 (1%)	11.3 (4%)
Camp Thunderrock	12 Oct 1991	605024	Z3712	232.4	56.5 (24%)	53.8 (23%)	0.0 (0%)	110.3 (47%)
Camp Thunderrock	3 Nov 1993	605044	SD-45	56.2	4.4 (8%)	3.6 (6%)	0.0 (0%)	8.0 (14%)
Camp Thunderrock	3 Nov 1993	605045	SD-46	55.3	4.7 (8%)	3.6 (6%)	0.0 (0%)	8.3 (14%)
Camp Thunderrock	4 Nov 1993	605047	SD-50	61.8	5.1 (8%)	2.3 (4%)	1.2 (2%)	8.6 (14%)
Camp Thunderrock	5 Nov 1993	605049	SD-53	28.2	3.1 (11%)	0.6 (2%)	0.0 (0%)	3.7 (13%)
Camp Thunderrock	5 Nov 1993	605050	SD-55	37.5	3.9 (10%)	0.5 (1%)	0.0 (0%)	4.4 (11%)
Camp Thunderrock	7 Nov 1993	405055	SD-62	45.5	5.4 (12%)	1.4 (3%)	0.0 (0%)	6.8 (15%)
U.S. Embassy	17 Jun 1991	605026	Y4397	612.7	9.4 (1%)	1.8 (<1%)	15.8 (3%)	27.0 (4%)
U.S. Embassy	20 Jun 1991	605027	Y5150	293.5	13.2 (5%)	50.5 (17%)	3.2 (1%)	66.9 (23%)
Military Hospital	17 Jun 1991	605029	Y4395	610.8	8.8 (1%)	1.7 (<1%)	17.6 (3%)	28.1 (4%)
Military Hospital	12 Oct 1991	605032	Z3711	121.6	26.0 (21%)	12.8 (11%)	3.4 (3%)	42.2 (35%)

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TABLE G-2-19. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED HIGH VOLUME PM-10 SAMPLES COLLECTED IN KUWAIT AND SAUDI ARABIA - 1991 SAMPLES

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
5339613	20 May 1991	Y2114	605025	us Embassy, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 1105.7 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-W x 2-3/4", (2) 7-1/2" x 2-3/4" - Very heavy particle loading - Brown/gray color
5322375	22 May 1991	Y2105	604999	KKMC, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 923.5 $\mu\text{g}/\text{m}^3$ - Four filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-3/4" x 2-3/4", (2) 6-1/2" x 2-3/4", (3) 2-1/4" x 1-1/2", (4) 47 mm circular section - Heavy particle loading - Brown color
5322339	23 May 1991	Y2104	605003	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 433.8 $\mu\text{g}/\text{m}^3$ - Three filter (glass-fiber) sections received on 21 Oct 1993: (1) 5" x 2-3/4", (2) 4-3/4" x 2-3/4" (with 47 mm circular section removed), (3) 6-1/4" x 2-3/4" - Very heavy particle loading - Tan/brown color
5322334	23 May 1991	Y2101	605013	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 338.7 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 8" x 2-3/4", (2) 8" x 2-7/8" (with a 47 mm circle removed) - Very heavy particle loading - Dark gray color
5322356	31 May 1991	Y3114	605000	KKMC, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 109.2 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-3/4" x 3", (2) 7-3/4" x 3" (with a 47 mm circle removed) - Heavy particle loading - Gray color
5322318	2 Jun 1991	Y3109	605004	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 296.6 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-3/4" x 3", (2) 7-3/4" x 2-3/4" (with 47 mm circular section removed) - Heavy particle loading - Black color

TABLE G-2-20. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED HIGH VOLUME PM-10 SAMPLES COLLECTED IN KUWAIT AND SAUDI ARABIA - 1991 SAMPLES

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
5248130	4 Jun 1991	Y3105	605014	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 360.7 $\mu\text{g}/\text{m}^3$ - Seven filter (glass-fiber) sections received on 21 Oct 1993: (1) 3-3/4" x 1-1/2", (2) 3-3/4" x 1-3/4", (3) 2-w x 1-5/8", (4) 2" x 1/3/4", and three 47-mm circular sections - Heavy particle loading - Black color
5295191	5 Jun 1991	Y4374	605028	Military Hospital, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 759.0 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-1/2" x 2-7/8", (2) 7-1/2" x 2-7/8" - Very heavy particle loading - Brown color
5207481	10 Jun 1991	Y3742	605009	Eskan Village, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 176.1 $\mu\text{g}/\text{m}^3$ - Four filter (glass-fiber) sections received on 21 Oct 1993: (1) 2-3/4" x 2", (2) ~3-3/4" x 2" (3) ~4" x 2", (4) 5" x 2" - Heavy particle loading - Dark gray color
5339627	11 Jun 1991	Y4469	605022	Camp Thunderock, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 365.7 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-3/4" x 1-7/8", (2) 7-3/4" x 1-7/8" - Heavy particle loading - Black color
5243136	11 Jun 1991	Y4392	605015	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 1855 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) ~7-1/4" x 2-7/8", (2) ~7-1/4" x 2-7/8" - Heavy particle loading - Gray color
5208829	11 Jun 1991	Y4461	605018	Ahmadi Hospital, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration : NA - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-3/4" x 1-7/8", (2) 7-3/4" x 2" - Heavy particle loading - Black color - AEHA document states that this is not a valid sample.

TABLE G-2-21.. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED HIGH VOLUME PM-10 SAMPLES COLLECTED IN KUWAIT AND SAUDI ARABIA - 1991 SAMPLES

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
5339672	13 Jun 1991	Y4401	605021	Camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 188.0 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-3/4" x 2-7/8", (2) 7-3/4" x 2-7/8" - Heavy particle loading - Black color
5207488	14 Jun 1991	Y4763	605010	Eskan Village, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 955 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) ~7-1/2 x 2", (2) ~7-w x 1-7/8" - Moderate particle loading - Dark gray color
5248188	17 Jun 1991	Y4397	605026	us Embassy, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 6127 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-1/4" x 3", (2) 7-1/4" x 3" - Very heavy particle loading - Brown color
5295153	17 Jun 1991	Y4395	605029	Military Hospital, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 610.8 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-1/4" x 2-7/8", (2) 7-1/2" x 2-7/8" - Vay heavy panicle loading - Brown color
5208839	19 Jun 1991	Y4787	605005	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 2826 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 8-w x 3", (2) 8-1/4" x 3" - Heavy particle loading - Uniform, dark color
5295163	20 Jun 1991	Y4769	605011	Eskan Village, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 6975 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-1/2" x 3", (2) 2-7/8" x 3" - Very heavy particle loading - Brown color
5334601	20 Jun 1991	Y5148	605019	Ahmadi Hospital, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 544.1 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-3/4" x 3", (2) 7-3/4" x 3" - Very heavy particle loading - Black color

TABLE G-2-22. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED HIGH VOLUME PM- 10 SAMPLES COLLECTED IN KUWAIT AND SAUDI ARABIA - 1991 SAMPLES

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
5334603	20 Jun 1991	Y5150	605027	US Embassy, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 293.5 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-1/2" x 1-7/8", (2) 7-1/2" x 1-7/8" - Heavy particle loading - Black color
5334604	20 Jun 1991	Y5151	605030	Military Hospital, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: NA - Two filter (glass-fiber) section received on 21 Oct 1993: (1) 7-3/4" x 3", (2) 7-3/4" x 3" - Heavy particle loading - Black color - AEHA document states that this is not a valid sample
5334638	26 Jun 1991	Y5642	605020	Ahmadi Hospital, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 191.0 $\mu\text{g}/\text{m}^3$ - Four filter (glass-fiber) sections received on 21 Oct 1993: (1) 3" x 3", (2) 5" x 2-7/8", (3) 3-1/4" x 2-7/8", (4) 5" x 2" - Heavy particle loading - Dark gray color
5322399	28 Jun 1991	Y5639	605001	KKMC, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 60.9 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-3/4" x 3", (2) 7-5/8" x 2-7/8" - Moderate particle loading - Gray color
5332661	7 Jul 1991	Y6482	605016	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 337.9 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 8" x 3", (2) 8" x 2-7/8" - Heavy particle loading - Black color
5248123	26 Jul 1991	Y8948	605002	KKMC, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 100.8 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7" x 2-7/8", (2) 7" x 2-7/8" - Heavy particle loading - Gray color

TABLE G-2-23. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED HIGH VOLUME PM-10 SAMPLES COLLECTED IN KUWAIT AND SAUDI ARABIA - 1991 SAMPLES

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
5208978	26 Jul 1991	Y8945	605031	Military Hospital, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: NA - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 8" x 3". (2) 8" x 2-3/4" - Heavy particle loading - Brown color - AEHA document states that this is not a valid sample
5208619	29 Jul 1991	Y8946	605006	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 215.6 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-1/2" x 3". (2) 7-1/2" x 3" - Heavy particle loading - Black color
5208620	29 Jul 1991	Y8947	605017	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 175.1 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-3/4" x 2-7/8", (2) 7-3/4" x 2-7/8" (with a 1" square missing) - Heavy particle loading - Dark gray color
5208922	31 Jul 1991	Y9110	605023	Camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 272.4 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-1/2" x 3". (2) 7-1/2" x 3" - Heavy particle loading - Brown color
5207461	1 Aug 1991	Y9826	605012	Eskan Village, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 1153 $\mu\text{g}/\text{m}^3$ - Two filter (glass-fiber) sections received on 21 Oct 1993: (1) 7-W x 3". (2) 7-1/2" x 3" - Moderate particle loading - Gray color
K-27	1 Oct 1991	PO51	605007	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 211.3 $\mu\text{g}/\text{m}^3$ - Two filter (quartz-fiber) sections received on 21 Oct 1993: (1) 3" x 8". (2) 3" x 7-1/2" (with a 1" square missing) - Heavy particle loading - Gray color

TABLE G-2-24. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED HIGH VOLUME PM-10 SAMPLES COLLECTED IN KUWAIT AND SAUDI ARABIA - 1991 SAMPLES

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sampk No.	Sample Location Site	Observations/Comments
K-18	12 Oct 1991	Z3712	605024	Camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 232.4 $\mu\text{g}/\text{m}^3$ - Two filter (quartz-fiber) sections received on 21 Oct 1993: (1) 7-3/4" x 1-7/8", (2) 7-3/4" x 1-7/8" (with a 1" square missing) - Very heavy panicle loading - Black color
K-17	12 Oct 1991	Z3711	605032	Military Hospital, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 121.6 $\mu\text{g}/\text{m}^3$ - Two filter (quartz) sections received on 21 Oct 1993: (1) 7-7/8" x 2-7/8", (2) 7-7/8" x 3" - Heavy particle loading - Black color
K-40	15 Oct 1991	Z3713	605008	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 167.0 $\mu\text{g}/\text{m}^3$ - Two filter (quartz-fiber) sections received on 21 Oct 1993: (1) 7-1/2" x 2-3/4", (2) 7-3/4" x 3" - Heavy particle loading - Gray color

TABLE G-2-25. **IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED HIGH VOLUME PM-10 SAMPLES COLLECTED IN KUWAIT AND SAUDI ARABIA - 1993 SAMPLES**

AEHA Field Sample No.	Date Collected	AEHA Filter ID	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
X-H2/CT/AS/SD-43	2 Nov 1993	SD-43	605043	camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 23.8 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
X-H2/CT/AS/SD-45	3 Nov 1993	SD-45	605044	Camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 562 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
X-H2/CT/AS/SD-46	3 Nov 1993	SD-46	605045	Camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - PM-10 concenuation: 553 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8' x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
X-H2/CT/AS/SD-48	3 Nov 1993	SD48	605046	Camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 27.8 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
01H2/3/AS/SD-6	3 Nov 1993	SD-6	605033	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concenuation: 56.4 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
X-H2/CT/AS/SD-50	4 Nov 1993	SD-50	605047	Camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - PM-10 concentration: 61.8 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10' quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray cola
X-H2/CT/AS/SD-52	4 Nov 1993	SD-52	605048	Camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - PM-10 concenuation: 385 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color

TABLE G-2-26. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED HIGH VOLUME PM-10 SAMPLES COLLECTED IN KUWAIT AND SAUDI ARABIA - 1993 SAMPLES

AEHA Field Sample No.	Date Collected	AEHA Filter ID	RJ Lee Group Sample No.	Sampk Location Site	Observations/Comments
01H2/3/AS/SD-7	4 Nov 1993	SD-7	605034	Khobar , Saudi Arabia	- PM-10 concentration: 57.2 $\mu\text{g}/\text{m}^3$ - 12 hr. ample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
01H2/3/AS/SD-9	4 Nov 1993	SD-9	605035	Khobar , Saudi Arabia	- PM-10 concentration: 40.3 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
X-H2/CT/AS/SD-53	5 Nov 1993	SD-53	605049	Camp Thunderrock, Kuwait	- PM-10 concentration: 282 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
X-H2/CT/AS/SD-55	5 Nov 1993	SD-55	605050	Camp Thunderrock, Kuwait	- PM-10 concentration: 375 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
01H2/3/AS/SD-11	5 Nov 1993	SD-11	605036	Khobar , Saudi Arabia	- PM-10 concentration: 95.4 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
01H2/3/AS/SD-13	5 Nov 1993	SD-13	605037	Khobar , Saudi Arabia	- PM-10 concentration: 30.1 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
X-H2/CT/AS/SD-56	6 Nov 1993	SD-56	605051	Camp Thunderrock, Kuwait	- PM-10 concentration: 34.5 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color

TABLE G-2-27. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED HIGH VOLUME PM-10 SAMPLES COLLECTED IN KUWAIT AND SAUDI ARABIA • 1993 SAMPLES

AEHA Field Sample No.	Date Collected	AEHA Filter ID	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
X-H2/CT/AS/SD-58	6 Nov 1993	SD-58	605052	Camp Thunderrock, Kuwait	- PM-10 concentration : 35.9 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8' x 10' quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
X-H2/CT/AS/SD-60	6 Nov 1993	SD-60	605053	Camp Thunderrock, Kuwait	- PM-10 concentration: 40.7 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8' x 10' quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
01H2/3/AS/SD-14	6 Nov 1993	SD-14	6 0 5 0 3 8	Khobar , Saudi Arabia	- PM-LO concentration: 74.8 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
01H2/3/AS/SD-16	6 Nov 1993	SD-16	605039	Khobar , Saudi Arabia	- PM-10 concentration: 31.8 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8' x 10" quartz-fiber filter received on 18 Nov 1993 - Light panicle loading - Gray color
X-H2/CT/AS/SD-61	7 Nov 1993	SD-61	605054	Camp Thunderrock, Kuwait	- PM-10 concentration: 36.4 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle lading - Gray color
X-H2/CT/AS/SD-62	7 Nov 1993	SD-62	605055	Camp Thunderrock, Kuwait	- PM-10 concentration: 455 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8' x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
01H2/3/AS/SD-17	7 Nov 1993	SD-17	605040	Khobar , Saudi Arabia	- PM-10 concentration: 562 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color

TABLE G-2-28. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED HIGH VOLUME PM-10 SAMPLES COLLECTED IN KUWAIT AND SAUDI ARABIA - 1993 SAMPLES

AEHA Field Sample No.	Date Collected	AEHA Filter ID	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
01H2/3/AS/SD-18	7 Nov 1993	SD-18	6 0 5 0 4 1	Khobar , Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 41.6 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8' x 10' quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color
01H2/3/AS/SD-20	9 Nov 1993	SD-20	605042	Khobar , Saudi Arabia	<ul style="list-style-type: none"> - PM-10 concentration: 66.8 $\mu\text{g}/\text{m}^3$ - 12 hr. sample - 8" x 10" quartz-fiber filter received on 18 Nov 1993 - Light particle loading - Gray color

TABLE G-2-29. SUMMARY OF CCSEM/TEM AERODYNAMIC MASS DISTRIBUTION RESULTS FOR PM-10 SAMPLES COLLECTED AT KHOBAR, SAUDI ARABIA (WT. %)

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	PM-10 Conc. ($\mu\text{g}/\text{m}^3$)	Particle Size Range (μm)				
				0.01-4	4-7.5	7.5-10	10-30	> 30
5322339	23 May 1991	605004	433.8	11	41	15	34	—
5322318	2 Jun 1991	605005	296.6 282.6	11	17	15	57	—
5208839	19 Jun 1991	605006		16	34	19	32	—
5208619	29 Jul 1991	605007	211.3 213.6	13	27	15	27	19
K-27	1 Oct 1991			6	17	18	58	—
K-40	15 Oct 1991	605008	167.0	16	36	19	29	—
01H2/3/AS/SD-6	3 Nov 1993	605033	56.4	5	15	6	55	18
01H2/3/AS/SD-7	4 Nov 1993	605034	57.2	10	22	14	54	—
01H2/3/AS/SD-11	5 Nov 1993			10	25	24	41	—
01H2/3/AS/SD-13	5 Nov 1993	605037	96.1	14	19	13	32	22
01HS/3/AS/SD-14	6 Nov 1993			9	32	16	43	—
01HS/3/AS-SD-18	7 Nov 1993	605041	74.8	9	13	12	45	20

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TABLE G-2-30. SUMMARY OF CCSEM/TEM AERODYNAMIC MASS DISTRIBUTION RESULTS FOR PM-10 SAMPLES COLLECTED AT CAMP THUNDEROCK, KUWAIT (WT. %)

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	PM-10 Conc. ($\mu\text{g}/\text{m}^3$)	Particle Size Range (μm)				
				0.01-4	4-7.5	7.5-10	10-30	> 30
5339627	11 Jun 1991	605022	365.7	13	33	16	38	—
5339672	13 Jun 1991	605021	188.0	10	24	12	46	—
11208922	31 Jul 1991	605023	272.4	23	31	17	43	—
K-18	12 Oct 1991	605044	232.4		14	8	56	—
X-H2/CT/AS/SD-45	3 Nov 1993	605045	56.2	14		13	27	16
X-H2/CT/AS/SD-46	3 Nov 1993		55.3	14		15	41	—
X-H2/CT/AS/SD-50	4 Nov 1993	605047	61.8	10	3-24	12	45	10
X-HS/CT/AS/SD-53	5 Nov 1993	605049	28.2	15	27	11	37	10
X-HS-CT/AS/SD-55	5 Nov 1993	605050	37.5	17	38	13	33	—
X-H2/CT/AS/SD-62	7 Nov 1993	605055	45.5	18	28	20	34	—

TABLE G-2-31. SUMMARY OF OCSEM/TEM PARTICLE-TYPE DATA FOR PM-10 SAMPLES COLLECTED AT KHOBAR, SAUDI ARABIA

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Si-rich and Mixed Clays		Ca-rich		C-rich		C-chain		Miscellaneous	
			Wt. %	(# Part.)	Wt. %	(# Part.)	Wt. %	(# Part.)	Wt. %	(# Part.)	Wt. %	(# Part.)
5322339	23 May 1991	605003	49	120	48	123	1	12	1	40	1	8
	2 Jun 1991	605004	26	53	40	77	16	76			6	11
5208839	19 Jun 1991	605005	46	96	54	95	6	50		21	6	16
		605006	29	82		94	10	60	B	31	4	11
52K-279	29 Jul 1991	605007	48	93	47	129	3	19	<1	19	2	8
K-40	15 Oct 1991	605008	36		33	75	5	40	1		4	13
01H2/3/AS/SD-6	3 Nov 1993	605033	31	126	46	67	18	28	1	17	32	15
01H2/3/AS/SD-7	4 Nov 1993	605034	30	75	75	133	8	41	1	7	15	13
01H2/3/AS/SD-11	5 Nov 1993	605036	18				5	24	7	211	1	7
01H2/3/AS/SD-13	5 Nov 1993	605037	22	64	20	67	21	75			30	32
01H5/3/AS/SD-14	6 Nov 1993	605038	19	39	70	188	3	9	S	28	3	8
01H5/3/AS-SD-18	7 Nov 1993	605041	20	64	26	84	38	29	9	32	7	13

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TABLE G-2-32. SUMMARY OF OCSEM/TEM PARTICLE-TYPE DATA FOR PM-10 SAMPLES COLLECTED AT CAMP THUNDEROCK, KUWAIT

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Si-rich and Mixed Clays		Ca-rich		C-rich		C-chain		Miscellaneous	
			Wt. %	(# Part.)	Wt. %	(# Part.)	Wt. %	(# Part.)	Wt. %	(# Part.)	Wt. %	(# Part.)
5339627	11 Jun 1991	605022	45		46		4	27	3	31	1	7
5339672	13 Jun 1991	605021	37	1083	37	112 82	14	55	8	73	4	7
5208922	31 Jul 1991	605023	21	116	47	97	6	42	<1	6	8	16
K-18	12 Oct 1991	605024	70	149		24		43	35	149	3	10
X-H2-CT/AS/SD-45	3 Nov 1993	605044			28	52	24	38	6	28		8
X-H2/CT/AS/SD-46	3 Nov 1993	605045	54	123	41	77	8	27	b	22	4	12
		605047	52	134				9	3			8
X-HS/CT/AS/SD-53	5 Nov 1993	605049	34	112	34	79	2:	33	6	28	2	13
X-HS-CT/AS/SD-55	5 Nov 1993	605050	50		37		7	13		25		11
X-H2/CT/AS/SD-62	7 Nov 1993	605055	39	118	37	102 98	12	25	6	26	8	10

TABLE G-2-33. SUMMARY OF CCSEWTEM CARBON CHAIN AGGLOMERATE DATA FOR PM-10 SAMPLES COLLECTED AT KHOBAR, SAUDI ARABIA

AEHA Field Sample No.	Date Collected	PM-10 Conc. $\mu\text{g}/\text{m}^3$	Carbon Chain Agglomerates	
			$\mu\text{g}/\text{m}^3$	%
			4.4	
5322339	23 May 1991	433.8	20.5	1.0
532018	2 Jun 1991	296.6		6.9
5208839	19 Jun 1991	282.6		1.9
			5.4	3.8
K-27619	29 Oct 1991	215.8	0.8	0.5
K-40	15 Oct 1991	167.0	2.2	1.3
		56.4		1.6
01H2/3/AS/SD-7	4 Nov 1993	57.2	0.9	2.3
01H2/3/AS/SD-11	5 Nov 1993	95.4	1.2	1.3
01H2/3/AS/SD-13	5 Nov 1993	30.1	3.0	10.1
01H2/3/AS/SD-14	6 Nov 1993	74.8	5.2	6.9
01H2/3/AS/SD-18	7 Nov 1993	41.6	4.5	10.8

TABLE G-2-34. SUMMARY OF CCSEM/TEM CARBON CHAIN AGGLOMERATE DATA FOR PM-10 SAMPLES COLLECTED AT CAMP THUNDEROCK, KUWAIT

AEHA Field Sample No.	Date Collected	PM-10 Conc. $\mu\text{g}/\text{m}^3$	Carbon Chain Agglomerates	
			$\mu\text{g}/\text{m}^3$	%
5339627	11 Jun 1991	365.7	13.9	3.8
5339672	13 Jun 1991	188.0	20.7	11.0
5208922	31 Jun 1991	272.4	0.5	0.2
K-18	12 Oct 1991	232.4	89.5	34.1
X-H2/CT/AS/SD-45	3 Nov 1993	56.2	5.1	9.0
X-H2/CT/AS/SD-46	3 Nov 1993	55.3	4.9	8.8
X-H2/CT/AS/SD-50	4 Nov 1993	61%	3.0	4.9
X-H2/CT/AS/SD-53	5 Nov 1993	28.2	1.2	8.2
X-H2/CT/AS/SD-55	5 Nov 1993	37.5	3.5	3.1
X-H2/CT/AS/SD-62	7 Nov 1993	45.5		7.8

TABLE G-2-35. METALS AND BROMINE RESULTS FOR INDUSTRIAL HYGIENE SAMPLES, µg/filter

AEHA Field Sample No.	Sample Location Site	AEHA Lab No.	RJLee Group Sample No.	V	Cr	Ni	Zn	Sr	Zr	Cd	As	Pb	Sb	Br
130-04	Khobar, Saudi Arabia	Y1109	601456	<0.26	0.73	<0.36	0.46	<0.26	<0.39	<0.0	<0.26	7.5	<1.0	<23
130-10	Khobar, Saudi Arabia	Y1112	603679	<0.30	0.67	<0.42	0.64	<0.30	<0.45	<0.0	0.30	<0.12	0.12	<31
T134-20	Camp Freedom, Kuwait	NA	601426	<0.24	0.38	<0.33	0.52	<0.24	<0.35	<0.0	<0.24	0.1	<0.94	<19
135-07	Field Blank	NA	601429	<0.40	0.60	<0.57	0.29	<0.40	<0.61	<0.0	<0.40	<0.16	<1.6	<20
T136-04	Camp Freedom, Kuwait	NA	601430	<0.15	0.4	0	<0.21	0.58	<0.15	<0.22	<0.0	<0.15	0.25	<0.59
137-11	Military Hospital, Kuwait	Y1836	601460	<0.37	0.76	<0.52	0.46	<0.37	<0.56	<0.0	<0.37	0.3	<1.5	<31
T140-05	Burgan Oil field, Kuwait	NA	601435	<0.20	0.41	<0.28	0.26	<0.20	<0.30	<0.0	0.20	0.09	<0.80	<12
140-11	Burgan Oil Field, Kuwait	Y1837	603693	<0.25	0.61	<0.35	0.62	<0.25	<0.38	<0.0	<0.25	<0.10	<1.0	<28
OF/FB/31	Field Blank	2539 I	603707	<0.28	0.52	<0.39	0.38	<0.28	<0.42	<0.0	<0.28	0.1	<1.1	<14

TABLE G-2-36. **MERCURY RESULTS FOR INDUSTRIAL HYGIENE SAMPLES, $\mu\text{g}/\text{filter}$**

AEHA Field Sample No.	Filter Type*	Date Collected	sample Location Site	RJ Lee Group Sample No.	Hg
T127-11	PVC	7 May 1991	Khobar, Saudi Arabia	603745	a1.030
R133-17	PVC	13 May 1991	Camp Freedom, Kuwait	601425	<0.040
T133-18	PVC	13 May 1991	Camp Freedom, Kuwait	601406	<0.040
R134-21	PVC	14 May 1991	Camp Freedom, Kuwait	601427	<0.060
R136-03	PVC	16 May 1991	Camp Freedom, Kuwait	601408	<0.040
T139-11	PVC	19 May 1991	Camp Thunderrock, Kuwait	601410	<0.060
R152-07	PVC	1 Jun 1991	Al-Jubayl, Saudi Arabia	603772	<0.020
R157-08	PVC	6 Jun 1991	Burgan Oil Field, Kuwait	603783	<0.020
R313-07	GF	NA	NA	603878	<0.020
F314-08	TEF	NA	NA	603876	Co.020
NA	NA	NA	NA	Rgt Blk	4.010

● GF Glass Fiber; TEF Teflon; PVC Polyvinyl chloride

TABLE G-2-37. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 25 MM MCE FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date	AEHA Collected	RJ Lee Lab No. Group Sample No.	Sample Location Site	Observations/Comments
130-01	10 May 1991	Y1107	01450 (SEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - AEHA nom that container broken in shipping - Approximately 1/4 of the filter received in a plastic petri dish on 2 Oct 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Approximately 1/4 of the filter received in a plastic petri dish on 19 Dec 1991 - Light tan color - Moderate particle loading; most particles agglomerated
130-03	10 May 1991	Y1108	601455 (SEM)	Kohbar, Saudi Arabia	<ul style="list-style-type: none"> - Approximately 1/2 of the filter received in a plastic petri dish on 20 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Tan color - Very heavy particle loading; most particles agglomerated
130-04	10 May 1991	Y1109	601456 (SEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - Approximately 1/2 of the filter received in a plastic petri dish on 20 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Tan color - Fingerprints at edge of filter - Very heavy particle loading; most particles agglomerated
130-06	10 May 1991	Y1110	603677 (SEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - AEHA notes that sample cassette not closed completely - Approximately 7/8 of the filter received in the sample collection cassette on 12 Nov 1992 - Tan color - Heavy particle loading
130-09	10 May 1991	Y1111	601457 (SEM) 35699 (TEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - Approximately 1/2 of the filter received in a plastic petri dish on 20 Dec 1991 - Approximately 1/8 of the filter received in the sample collection cassette on 12 Nov 1992 - Light tan color - Moderate to heavy particle loading, some particles agglomerated

TABLE G-2-38. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 25 MM MCE FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
130-10	10 May 1991	Y1112	603679 (SEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - Field Blank - The entire filter received in the sample collection cassette on 12 Nov 1992 - White color - No particles observed
13301	13 May 1991	Y1621	600750 (SEM) 601451 (SEMI) 35493 (TEM)	Camp - Kuwait	<ul style="list-style-type: none"> - Approximately 1/4 of the filter received in a plastic petri dish on 2 Oct 1991 - Approximately 1/3 of the filter received in a plastic petri dish on 19 Dec 1991 (petri dish received cracked) - Approximately 1/8 of the filter received in the sample collection cassette on 12 Nov 1992 - Gray color - Light to moderate particle loading
133M	13 May 1991	Y1622	603681 (SEM) 35551 (TEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Approximately 1/4 of the filter received in a plastic petri dish on 2 Oct 1991 - Approximately 1/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Good particle loading
133-13	13 May 1991	Y1623	600752 (SEM) 601452 (SEM) 35495 (TEM) 35552 (TEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Approximately 1/4 of the filter received in a plastic petri dish on 2 Oct 1991 - Approximately 1/4 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/8 of the filter received in the sample collection cassette on 12 Nov 1992 - Light to medium gray color - Light particle loading
133-14	13 May 1991	Y1624	601458 (SEM) 35492 (TEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Approximately 1/3 of the filter received in a plastic petri dish on 20 Dec 1991 - Approximately 1/8 of the filter received in the sample collection cassette on 12 Nov 1992 - Gray color - Moderate particle loading
134-12	14 May 1991	Y1833	603684 (SEM) 35553 (TEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Approximately 1/4 of the filter received in plastic petri dish on 2 Oct 1991 - Approximately 1/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Gray color - Heavy particle loading

TABLE G-2-39. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 25 MM MCE FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sampk No.	sample Location Site	Observations/Comments
134-13	14 May 1991	Y1834	603685 (SEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Black color - Heavy particle loading
134-19	14 May 1991	Y1625	600754 (SEM) 35700 (TEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Field Blank - Approximately 1/4 of the filter received in plastic petri dish on 2 Oct 1991 - White color - No particles observed
137-10	17 May 1991	Y1835	601459 (SEM)	Military Hospital, Kuwait	<ul style="list-style-type: none"> - Approximately 1/2 of the filter received in a plastic petri dish on 20 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Tan color - Fingerprint at edge of filter - Vay heavy particle loading. most particles agglomerated
137-11	17 May 1991	Y1836	601460 (SEM)	Military Hospital, Kuwait	<ul style="list-style-type: none"> - Approximately 1/2 of the filter received in a plastic petri dish on 20 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Tan color - Very heavy particle loading; many particles agglomerated
139-08	19 May 1991	Y1983	603689 (SEM)	Camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Light tan color - Light particle loading
139-09	19 May 1991	Y1984	603690 (SEM)	Camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - Approximately 2/3 of the filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Moderate to heavy panicle loading
139-10	19 May 1991	Y1985	603691 (SEM)	Camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - Field Blank - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - whiucola - No particles observed

TABLE G-2-40. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 25 MM MCE FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
139-16	19 May 1991	Y1886	603692 (SEM)	Camp Thundercock, Kuwait	<ul style="list-style-type: none"> - Field Blank - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Whitecola - Filter slightly tom - No particles observed
140-11	20 May 1991	Y1837	600755 (SEMI) 603693 (SEM) 35554 (TEM)	Burgan Oil Field, Kuwait	<ul style="list-style-type: none"> - Approximately 1/4 of the filter received in a plastic petri dish on 2 Oct 1991 - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Light black color - Fingerprint observed on filter surface - Very heavy particle loading
140-12	20 May 1991	Y1838	600756 (SEM) 603694 (SEM)	Burgan Oil Field, Kuwait	<ul style="list-style-type: none"> - Approximately 1/4 of the filter received in a plastic petri dish on 2 Oct 1991 - Approximately 1/5 of the filter received in the sample collection cassette on 12 Nov 1992 - Black color. some particles lost - Fingerprint observed on filter surface - Very heavy particle loading
142-05	20 May 1991	Y1839	603695 (SEM)	Not Available	<ul style="list-style-type: none"> - Field Blank - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - White color - No particles observed
142-06	22 May 1991	Y1840	601461 (SEM)	Not Available	<ul style="list-style-type: none"> - Field Blank - Approximately 1/2 of the filter received in a plastic petri dish on 20 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - White color - Very few particles observed
149M	29 May 1991	Y3069	601446 (SEM) 35491 (TEM)	Dammon Port, Saudi Arabia	<ul style="list-style-type: none"> - Approximately 1/3 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/g of the filter received in the sample collection cassette on 12 Nov 1992 - Gray color - Moderate particle loading

TABLE G-241. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 25 MM MCE FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location site	Observations/Comments
152-17	1 Jun 1991	Y3070	601447 (SEM)	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - Approximately 1/3 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 2/5 of the filter received in the sample collection cassette on 12 Nov 1992 - Very light gray color - Heavy particle loading; most particles agglomerated
152-18	1 Jun 1991	Y3071	601448 (SEM)	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - Approximately 1/4 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 2/3 of the filter received in the sample collection cassette on 12 Nov 1992 - Very light gray color - Moderate to heavy particle loading; most particles agglomerated
152-33	1 Jun 1991	Y3072	601462 (SEM) 35494 (TEM)	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - Approximately 1/3 of the filter received in a plastic petri dish on 20 Dec 1991 - Approximately 1/8 of the filter received in the sample collection cassette on 12 Nov 1992 - Very tight gray color - Moderate particle loading
153-04	2 Jun 1991	Y3073	601449 (SEM)	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - Field Blank - Approximately 1/3 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/3 of the filter received in the sample collection cassette on 12 Nov 1992 - White color - Very few particles observed

TABLE G-242. SUMMARY OF CCSEM/TEM AERODYNAMIC MASS DISTRIBUTION RESULTS FOB INDUSTRIAL HYGIENE SAMPLES COLLECTED ON MCE FILTERS IN KUWAIT (WT. %)

ABHA Field Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	Particle Size Range (μm)				
				0.01-4	4-7.5	7.5-10	10-30	> 30
133-01	13 May 1991	Camp Freedom	601451/35493	52	31	11	6	—
133-02	13 May 1991	Camp Freedom	600751/35551	46	39	12	4	—
133-13	13 May 1991	Camp Freedom	601452/35495	50	29	9	13	—
133-14	13 May 1991	Camp Freedom	601458/35492	40	42	8	10	—
134-12	14 May 1991	Camp Freedom	603684/35553	48	34	7	5	7

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TABLE G-243. SUMMARY OF CCSEM/TEM AERODYNAMIC MASS DISTRIBUTION RESULTS FOR INDUSTRIAL HYGIENE SAMPLES COLLECTED ON MCE FILTERS IN SAUDI ARABIA (WT. %)

ABHA Field Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	Particle Size Range (μm)				
				0.01-4	4-7.5	7.5-10	10-30	> 30
130-09	10 May 1991	Khobar	601457/35699	41	28	12	24	—
149-03	29 May 1991	Dammam Port	601446/35491	30	35	11	12	—
152-33	1 June 1991	Al Jabayl	601462/35494		50		9	—

TABLE G-2-44. SUMMARY OF CCSEM/TEM PARTICLE-TYPE DATA FOR INDUSTRIAL HYGIENE SAMPLES COLLECTED ON MCE FILTERS IN KUWAIT

AEHA Field Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	Si-rich and Mixed Clays		Ca-rich		C-rich		Miscellaneous	
				Wt. %	# Part.	Wt. %	# Part.	Wt. %	# Part.	Wt. %	# Part.
133-01	13 May 1991	Camp Freedom	601451/35493	61	120	38	115	1	5	1	4
133-02	13 May 1991	Camp Freedom	600751/35551	53	138	44	83	3	6	1	2
133-13	13 May 1991	Camp Freedom	601452/35495	31	101	53	120	15	47	1	9
133-14	13 May 1991	Camp Freedom	601458/35492	31	105	25	97	41	54	4	19
134-12	14 May 1991	Camp Freedom	603684/35553	44	134	42	133	12	57	2	8

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TABLE G-2-45. SUMMARY OF CCSEM/TEM PARTICLE-TYPE DATA FOR INDUSTRIAL HYGIENE SAMPLES COLLECTED ON MCE FILTERS IN SAUDI ARABIA

AEHA Field Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	Si-rich and Mixed Clays		Ca-rich		C-rich		Miscellaneous	
				Wt. %	# Part.	Wt. %	# Part.	Wt. %	# Part.	Wt. %	# Part.
130-09	10 May 1991	Khobar	601457/35699	46	119	54	134	< 1	17	—	—
14943	29 May 1991	Dammam Port	601446/35491	41	103	43	103	7	48	9	20
152-33	1 June 1991	Al-Jubayl	601462/35494	11	25	86	202	3	31	1	10

TABLE G-246. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 37 MM PVC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
127-08	7 May 91	600763 (SEM)	Not Available	<ul style="list-style-type: none"> - Field Blank - Entire filter received in the sample collection cassette on 2 Oct. 1991 - White color - Small (~1μm) spherical particle clusters observed
R127-10	7 May 91	6 0 3 7 6 7 (SEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Light to moderate particle loading
T127-11	7 May 91	603745 (SEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - Total Fraction - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Very heavy particle loading
T127-12	7 May 91	603755 (SEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - Total Fraction - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Moderate particle loading with high concentration in center of filter
R130-05	10 May 91	603768 (SEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - off-white to very light gray color - Light particle loading
T130-08	10 May 91	603761 (SEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - Total - - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992; tan color - Tan or yellow deposition in center of filter - Uneven distribution
R133-05	13 May 91	600758 (SEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in sample collection cassette on 2 Oct 1991 - Light gray color - Light particle loading

TABLE G-2-47. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 37 MM PVC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
T133-06	13 May 91	603775 (SEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Total Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - Light tan color - Heavy particle loading
R133-17	13 May 91	601425 (SEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Very light particle loading
T133-18	13 May 91	601406 (SEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Total Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 18 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Light particle loading
R134-03	14 May 91	600759 (SEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in sample collection cassette on 2 Oct 1991 - Dark gray color - Moderate to heavy panicle loading of fine (<2.5µm) particles; many agglomerated particles observed
R134-07	14 May 91	600760 (SEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Total Fraction - Entire filter received in sample collection cassette on 2 Oct 1991 - Dark gray color - Moderate particle loading
R134-08	14 May 91	603766 (SEM)	EOD Safeholding, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Light to moderate particle loading
R134-16	14 May 91	603777 (SEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - Light to moderate gray color - Light to moderate particle loading

TABLE G-2-48. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 37 MM PVC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
134-17	14 May 91	603776 (SEM)	Not Available	- Field Blank - Entire filter received in the sample collection cassette on 12 Nov 1992 White color No particles observed
T134-20	14 May 91	601426 (SEM)	Camp Freedom, Kuwait	- Total Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 Black color Very heavy particle loading; agglomerated particles cover entire surface of filter
R134-21	14 May 91	601427 (SEM)	Camp Freedom, Kuwait	- Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 Black color - Heavy particle loading
R135-04	15 May 91	601428 (SEM)	US Embassy, Kuwait	- Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 Light gray color - Light particle loading
T135-05	15 May 91	601407 (SEM)	US Embassy, Kuwait	- Total Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 18 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Very light gray color - Very light particle loading; particle chain agglomerates observed
135-07	15 May 91	601429 (SEM)	Not Available	- Field Blank - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - White to very light gray color - No particles observed

TABLE G-2-49. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 37 MM PVC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
T135-11	15 May 91	603760 (SEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Total Fraction - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Very light gray color - Light particle loading, uneven distribution
R136-03	16 May 91	601408 (SEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 18 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Black color with fingerprints near edge of filter - Very heavy particle loading
T136-04	16 May 91	601430 (SEM)	Camp Freedom, Kuwait	<ul style="list-style-type: none"> - Total Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Black color with fingerprints at edge of filter - Very heavy particle loading
13701	17 May 91	603751 (SEM)	Not Available	<ul style="list-style-type: none"> - Field Blank - Entire filter received in the sample collection cassette on 12 Nov 1992 - White color - Particles absent
T137-02	17 May 91	600761 (SEM)	Military Hospital, Kuwait	<ul style="list-style-type: none"> - Total Fraction - Entire filter received in the sample collection cassette on 2 Oct 1991 - Tan color - Moderate to heavy particle loading, some particles agglomerated
T137-03	17 May 91	600761 (SEM)	Military Hospital, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection cassette on 2 Oct 1991 - Tan color - Moderate to heavy particle loading, some particles agglomerated
T138-03	18 May 91	601431 (SEM)	Military Hospital, Kuwait	<ul style="list-style-type: none"> - Total Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Very light gray color - Moderate to heavy particle loading

TABLE G-2-50. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 37 MM PVC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
R138-07	18 May 91	601409 (SEM)	Military Hospital, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 18 Dec 1991 - Light gray color - Moderate particle loading
T139-02	19 May 91	601432 (SEM)	Ahmadi Hospital, Kuwait	<ul style="list-style-type: none"> - Total Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Light particle loading
R139-03	19 May 91	601433 (SEM)	Ahmadi Hospital, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collation cassette on 12 Nov 1992 - Medium gray color - Very light particle loading
T139-11	19 May 91	601410 (SEM)	Camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - Total Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 18 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - white color - Very light particle loading
R13P12	19 May 91	401411 (SEM)	Camp Thunderrock, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 18 Dec 1991 - Approximately 1/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Very light gray color - Light particle loading
139-19	19 May 91	601434 (SEM)	Not Available	<ul style="list-style-type: none"> - Field Blank - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - White color - No particles observed

TABLE G-2-51. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 37 MM PVC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
T140-05	20 May 91	601435 (SEM)	Burgan Oil Field, Kuwait	<ul style="list-style-type: none"> - Total Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Black color - Very heavy particle loading
R140-06	20 May 91	601412 (SEM)	Burgan Oil Field, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 18 Dec 1991 - Approximately 1/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Very light gray color - Light particle loading
R140-07	20 May 91	603769 (SEM)	Ahmadi Hospital, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992; - Outside of sampling cassette speckled with oil droplets - Medium gray color - Light to moderate particle loading
142-09	22 May 91	603759 (SEM)	Not Available	<ul style="list-style-type: none"> - Field Blank - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Light tan or yellow color in center of filter - Particles observed on the filter
R143-17	23 May 91	603782 (SEM)	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Very light gray to white color - Very light particle loading
T143-18	23 May 91	603770 (SEM)	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - Total Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - very light gray color - Light to moderate particle loading
R144-01	24 May 91	603765 (SEM)	Damman Port, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Moderate particle loading

TABLE G-2-52. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 37 MM WC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
T144-02	24 May 91	603779 (SEM)	Damman Port, Saudi Arabia	<ul style="list-style-type: none"> - Total Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Light to moderate particle loading
T145-05	25 May 91	603752 (SEM)	Damman Port, Saudi Arabia	<ul style="list-style-type: none"> - Total Fraction - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Medium to dark gray color - Heavy particle loading
R145-06	25 May 91	603781 (SEM)	Damman Port, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 15'92 - Light gray color - Very light particle loading
R147-02	27 May 91	601436 (SEM)	Damman Port, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Heavy loading of fine agglomerated particles
T147-03	27 May 91	601437 (SEM)	Damman Port, Saudi Arabia	<ul style="list-style-type: none"> - Total Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Gray color - Moderate particle loading
T148-09	28 May 91	601413 (SEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - Total Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 18 Dec 1991 - Light gray color - Light to moderate particle loading
R148-10	28 May 91	601438 (SEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Very light gray to white color - Very light particle loading

TABLE G-2-53. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 37 MM PVC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
T148-18	28 May 91	603773 (SEM)	Damman Port, Saudi Arabia	<ul style="list-style-type: none"> - Total Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - Gray color - Moderate to heavy particle loading
R148-19	28 May 91	603780 (SEM)	Damman Port, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - Medium gray color - Moderate to heavy particle loading
T149-06	29 May 91	603757 (SEM)	Damman Port, Saudi Arabia	<ul style="list-style-type: none"> - Total Fraction - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Very light gray color - Light particle loading
R149-07	29 May 91	603762 (SEM)	Damman Port, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Moderate particle loading
149-18	29 May 91	603746 (SEM)	Not Available	<ul style="list-style-type: none"> - Field Blank - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - White color - No particles observed
T150-04	30 May 91	601439 (SEM)	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - Total Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - White to very light gray color - Light particle loading
R150-05	30 May 91	601440 (SEM)	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - White to very light gray color - Light particle loading

TABLE G-2-54. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 37 MM PVC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
R150-09	30 May 91	603748 (SEM)	Damman Port, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection on 12 Nov 1992 - Light gray color - Light to moderate particle loading
151-05	31 May 91	603758 (SEMI)	Not Available	<ul style="list-style-type: none"> - Field Blank - Entire filter received in the sample collection cassette on 12 Nov 1992 - whitecola - No particles observed
T152-05	1 Jun 91	603778 (SEM)	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - Total Fraction - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Very light gray to off-white color - Very light particle loading
R152-06	1 Jun 91	601441 (SEM)	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Very heavy particle loading, most particles agglomerated
R152-07	1 Jun 91	603772 (SEW)	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - Medium graycola - Heavy particle loading
R152-08	1 Jun 91	603747 (SEM)	Al-Jubayl, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Light to moderate particle loading
R152-09	1 Jun 91	600757 (SEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection cassette on 2 Oct 1991 - Gray color - Heavy particle loading; most particles agglomerated

TABLE G-2-55. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 37 MM PVC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
153-02	2 Jun 91	603753 (SEM)	Not Available	<ul style="list-style-type: none"> - Field Blank - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - White color - No particles observed
R155-08	4 Jun 91	601442 (SEM)	Ahmadi Hospital, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Very light gray color - Light particle loading
T155-09	4 Jun 91	601443 (SEMI)	Ahmadi Hospital, Kuwait	<ul style="list-style-type: none"> - Total Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Very Light gray color - Light particle loading
R155-14	4 Jun 91	603749 (SEM)	Al-Wafra, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - Gray color - Moderate to heavy particle loading
T155-15	4 Jun 91	603750 (SEM)	Al-Wafra, Kuwait	<ul style="list-style-type: none"> - Total Fraction - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Gray color - Heavy particle loading
R156-01	5 Jun 91	603774 (SEM)	Military Hospital, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - Off-white to light gray color - Light to moderate particle loading
R156-07	5 Jun 91	601444 (SEM)	Al-Wafra, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Medium gray color - Moderate to heavy particle loading; some particles agglomerated

TABLE G-2-56. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 37 MM PVC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
R156-13	5 Jun 91	603756 (SEM)	Amadi Hospital, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Light to moderate particle loading
R157-04	6 Jun 91	601445 (SEM)	Burgan Oil Field, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Approximately 1/2 of the filter received in a plastic petri dish on 19 Dec 1991 - Approximately 1/2 of the filter received in the sample collection cassette on 12 Nov 1992 - Black color - Very heavy particle loading
R157-08	6 Jun 91	603783 (SEM)	Burgan Oil Field, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Moderate to heavy particle loading
R157-11	6 Jun 91	603763 (SEM)	Burgan Oil Field, Kuwait	<ul style="list-style-type: none"> - Respirable Fraction - Entire filter received in the sample collection cassette on 12 Nov 1992 - Light gray color - Moderate particle loading
T157-17	6 Jun 91	603764 (SEM)	Burgan Oil Field, Kuwait	<ul style="list-style-type: none"> - Total Fraction - Approximately 3/4 of the filter received in the sample collection cassette on 12 Nov 1992 - Dark gray color - Heavy and uneven particle loading
160-04	9 Jun 91	603754 (SEM)	Not Available, Kuwait	<ul style="list-style-type: none"> - Field Blank - Entire filter received in the sample collection cassette on 12 Nov 1992 - White color - No particles observed
160-05	9 Jun 91	603771 (SEM)	Not Available	<ul style="list-style-type: none"> - Field Blank - Entire filter received in the sample collection cassette on 12 Nov 1992 - Filter badly damaged - White color - No particles observed

TABLE G-2-57, SUMMARY OF CCSEM AERODYNAMIC MASS DISTRIBUTION RESULTS FOR INDUSTRIAL HYGIENE SAMPLES COLLECTED ON PVC FILTERS IN KUWAIT (WT. %)

AEHA Field Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	Particle Size Range (µm)				
				1-4	4-7.5	7.5-10	10-30	> 30
T134-07	14 May 1991	Camp Freedom	600760	31	48	21		
R135-04	15 May 1991	US Embassy	601428	73	28			
T137-02	17 May 1991	Military Hospital	600761	6	36	27	30	-
R137-03	17 May 1991	Military Hospital	600762	14	58	9	19	-
T138-03	18 May 1991	Military Hospital	601431	57	31	18	38	-
R138-07	18 May 1991	Military Hospital	601409	64	23	17	3	-
R156-01	5 Jun 1991	Military Hospital	603774		36	1		
R139-12	19 May 1991	Camp Thunderock	601411	69	31	-	-	-
T139-02	19 May 1991	Ahmadi Hospital	601432	9	37	23	32	-
R155-08	4 Jun 1991	Ahmadi Hospital	601442	55	37	8	-	-
T155-09	4 Jun 1991	Ahmadi Hospital	601443	18	42	19	21	
R156-13	5 Jun 1991	Ahmadi Hospital	603756	44	34	1	14	
R140-06	20 May 1991	Burgan Oil Field	601412	63	27	18	12	
R157-11	6 Jun 1991	Oil Field				5	-	-
T157-08	6 Jun 1991	Burgan Oil Field	603783	26	58	5	14	-
R156-07	5 Jun 1991	Al-Wafra	601444	41	46	13	-	-

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TABLE O-2-58, SUMMARY OF CCSEM AERODYNAMIC MASS DISTRIBUTION RESULTS FOR INDUSTRIAL HYGIENE SAMPLES COLLECTED ON PVC FILTERS IN SAUDI ARABIA (WT. %)

AEHA Field Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	Particle Size Range (µm)				
				1-4	4-7.5	7.5-10	10-30	> 30
T127-12	7 May 1991	Khobar	603755	13	28	18	41	-
T143-18	23 May 1991	Al-Jubayl	603770	41	16		12	-
R148-09	28 May 1991	Al-Jubayl	601413	2	28	2	57	-
R148-10	28 May 1991	Al-Jubayl	601438	72				-
T150-04	30 May 1991	Al-Jubayl	601439	7	30	36	26	-
R152-08	30 May 1991	Al-Jubayl	603747	80	40	14	4	-
T144-02	24 May 1991	Damman Port	603779	12	36	23	29	-
T147-03	27 May 1991	Damman Port	601437	17	44	32	7	-
T148-18	28 May 1991	Damman Port	603773	27	47	9	17	

TABLE O-2-59. SUMMARY OF CCSEM PARTICLE-TYPE DATA FOR INDUSTRIAL HYGIENE SAMPLES COLLECTED ON PVC FILTERS IN KUWAIT

AEHA Field Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	Si-rich and Mixed Clays		Ca-rich		C-rich		Miscellaneous	
				Wt. %	# Part.	Wt. %	# Part.	Wt. %	# Part.	Wt. %	# Part.
T134-07	14 May 1991	Camp Freedom	600760	43	74	46	64	6	9	5	19
R135-04	15 May 1991	US Embassy	601428	51	95	38	52	7	13	4	12
T137-02	17 May 1991	Military Hospital	600761	46	105	53	118	1	10	< 1	9
R137-03	17 May 1991	Military Hospital	600762	33	96	66	140	1	4	C 1	5
T138-03	18 May 1991	Military Hospital	601431	37	122	49	97		3	1	5
R138-07	18 May 1991	Military Hospital	601409	64	155	31	79	14	8	5	8
R156-01	5 Jun 1991	Military Hospital	603774	44	110	51	114	1	2		12
R139-12	19 May 1991	Camp Thundercock	601411	45	87	48	90	1	9	3	14
T139-02	19 May 1991	Ahmadi Hospital	601432	55	71	60	49	< 1	3	2	10
R155-08	4 Jun 1991	Ahmadi Hospital	601442		131	41	92	2	6		8
T155-09	4 Jun 1991	Ahmadi Hospital	601443	63	143	36	77		9	< 1	6
R156-13	5 Jun 1991	Ahmadi Hospital	603756	51	148	38	120	1	4	10	8
R140-06	20 May 1991	Burgan Oil Field	601412	32		51			5	4	24
R157-11	6 Jun 1991	Burgan Oil Field	603763	33	89 86	62	127 139	13	3	5	12
Tt 57-08	6 Jun 1991	Burgan Oil Field	603783	31	113	68	155	< 1	3	1	7
R156-07	5 Jun 1991	Al-Wafra	601444	52	122	41	95	4	15	4	8

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TABLE O-2-60. SUMMARY OF CCSEM PARTICLE-TYPE DATA FOR INDUSTRIAL HYGIENE SAMPLES COLLECTED ON PVC FILTERS IN SAUDI ARABIA

AEHA Field Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	Si-rich and Mixed Clays		Ca-rich		C-rich		Miscellaneous	
				Wt. %	# Part.	Wt. %	# Part.	Wt. %	# Part.	wt. %	# Part.
T127-12	7 May 1991	Khobar	603755	15	46	81	163	< 1	1	4	15
T143-18	23 May 1991	Al-Jubayl	603770	43	101	49	116	8	19	< 1	3
R148-09	28 May 1991	Al-Jubayl	601413	36	87	54		3	8	7	8
R148-10	28 May 1991	Al-Jubayl	601438	48	101	44	97 80	1	5	7	10
T150-04	30 May 1991	Al-Jubayl	601439	3	12	86	188	3	20	7	23
R150-05	30 May 1991	At-Jubayl	601440	22	30	76	151	1		1	4
RI 52-08	1 Jun 1991	At-Jubayl	603747	10	27	82	218	4	15	5	15
T144-02	24 May 1991	Damman Port	603779	7	39	77	162	1		3	18
T147-03	27 May 1991	Damman Port	601437	19	58	66	121	1	10		15
T148-18	28 May 1991	Damman Port	603773	32	115		138		10	1	3

TABLE G-261. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 25 MM PC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
OF/AS/27	31 Oct 1991	Z5384	603700 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Heavy and non-uniform particle loading - Large amount of particles greater than 100 μm (and) found in cassette and on filter
OF/AS/26	31 Oct 1991	Z5385	603701 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Small brown spot observed on the filter - Backing pad was received cut in half in the collection cassette - Very tight particle loading with a few sub-micron particles observed
OF/AS/44	31 Oct 1991	Z5386	603702 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Very light particle loading
OF/AS/45	31 Oct 1991	Z5387	603703 (SEM) 46331 (TEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - light particle loading - Most of the particles ranging between 1 and 10 μm; some sub-micron particles observed
OF/AS/46	1 Nov 1991	Z5388	603704 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Very light particle loading - Most of the particles observed ranged from 5 to 10 μm in size - A small amount of sub-micron particles observed
OF/AS/47	1 Nov 1991	Z5389	603705 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light particle loading

TABLE G-2-62. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 25 MM PC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
OF/AS/48	1 Nov 1991	Z5390	603706 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light particle loading
OF/FB/31	NA	25391	603707 (SEMI)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Field Blank - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - A few panicles observed
OF/AS/56	2 Nov 1991	Z5392	603708 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light particle loading; most of the particle population ranging between 1 and 10 μm - Some sub-micron particles observed - Loading appears to be non-uniform in areas
OF/AS/58	2 Nov 1991	25393	603709 (SEM) 46336 (TEM)	Oil fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Moderate particle loading - Majority of particle population between 0.5 and 10 μm
OF/AS/60	2 Nov 1991	Z5394	603710 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light particle loading
OF/AS/66	3 Nov 1991	25395	603711 (SEM) 46340 (TEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light to moderate particle loading - Majority of panicle population < 10 μm - A high number of sub-micron particles observed

TABLE G-2-63. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 25 MM PC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
OF/AS/67	3 Nov 1991	Z5396	603712 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Filter has an uneven distribution of particles - Large particles observed adhering to the walls of the cassette - Macroscopic particles as large as ~200 µm also observed on filter
OF/AS/68	3 Nov 1991	Z5397	603713 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Moderate particle loading - Majority of particle population ranging from 0.5 to 10 µm - A high number of sub-micron particles observed
OF/AS/43	3 Nov 1991	25398	603714 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light particle loading - Particles were observed on both sides of the filter.
OF/FB/32	NA	25399	603715 (SEM) 46324 (TEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Field Blank - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light particle loading
OF/AS/42	4 Nov 1991	Z5400	603716 (SEM) 46330 (TEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Moderate particle loading - Majority of particle population ranging between 1 and 10 µm - Many sub-micron particles observed - A portion of the filter was wrinkled

TABLE G-2-64. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 25 MM PC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
OF/AS/28	4 Nov 1991	Z5401	603717 (SEM) 46323 (TEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light to moderate particle loading with particles ranging between 1 and 20 μm - Some sub-micron particles observed
OF/AS/69	4 Nov 1991	Z5402	603718 (SEMI) 46342 (TEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light particle loading - Particles ranging between 1 and 10 μm with some sub-micron particles observed
OF/AS/50	4 Nov 1991	Z5403	603719 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Sample collection cassette received on 11 Nov 1992 - Filter missing from the collection cassette
OF/AS/29	5 Nov 1991	Z5404	603720 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Sample collection cassette received on 11 Nov 1992 - Filter missing from the collection cassette
OF/AS/70	5 Nov 1991	Z5405	603721 (SEM) 4.6343 (TEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light to moderate particle loading with particles ranging from sub micron to 10 μm
OF/AS/41	5 Nov 1991	Z5406	603722 (SEM)	Oil Fields, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Very light particle loading
MH/AS/52	6-7 Nov 1991	Z5407	603723 (SEM)	Military Hospital, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Extremely light particle loading with particles ranging from 10 to 20 μm - Very few particles <10 μm observed

TABLE G-2-65. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 25 MM PC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
UN/AS/33	6-7 Nov 1991	Z5408	603724 (SEM) 46325 (TEM)	UN Building, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light particle loading - Majority of particles ranging between 1 and 10 μm - A small number of sub-micron particles observed
MH/AS/53	7-g Nov 1991	Z5409	603725 (SEM) 46333 (TEM)	Military Hospital, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Moderate to heavy particle loading with particles ranging from sub-micron to 20 μm
UN/AS/38	7-g Nov 1991	Z5410	603726 (SEM) 46327 (TEM)	UN Building, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Moderate particle loading - Majority of particles between 1 and 10 μm - Some sub-micron particles observed
MH/AS/63	g-9 Nov 1991	Z5411	603727 (SEM) 46337 (TEM)	Military Hospital, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Moderate particle loading with particles ranging from sub-micron to 10 μm
UN/AS/73	8-9 Nov 1991	25412	603728 (SEM) 46346 (TEM)	UN Building, Kuwait	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Moderate particle loading with particles ranging from sub-micron to 10 μm

TABLE G-2-66. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 25 MM PC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
MH/AS/64	9-10 Nov 1991	25413	603729 (SEM) 46338 (TEM)	Military Hospital, Kuwait	- Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light to moderate panicle loading - Majority of particles sub-micron with remainder of population ranging from 1 to 10 μ m
MH/FB/74	NA	Z5414	603730 (SEM)	Military Hospital, Kuwait	- Field Blank - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Both sides of the filter have very light particle loading
UN/AS/65	9-10 Nov 1991	25415	603731 (SEM) 46339 (TEM)	UN Building, Kuwait	- Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Majority of particles sub-micron with remainder of population ranging from 1 to 10 μ m - Light to moderate particle loading
MH/AS/54	11-12 Nov 1991	Z5416	603732 (SEM) 46334 (TEM)	Military Hospital, Kuwait	- Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Majority of particles sub-micron with remainder of population ranging from 1 to 10 μ m - Light to moderate particle loading
UN/AS/55	11-12 Nov 1991	25417	603733 (SEM) 46335 (TEM)	UN Building, Kuwait	- Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light to moderate particle loading - Majority of particles sub-micron with remainder of population ranging from 1 to 10 μ m
UN/M/37	12-13 Nov 1991	25418	603734 (SEM)	UN Building, Kuwait	- Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light to moderate particle loading - Majority of particles sub-micron with remainder of population ranging from 1 to 10 μ m

TABLE G-2-67. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 25 MM PC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
MH/FB/34	NA	Z5419	603735 (SEM)	Military Hospital, Kuwait	<ul style="list-style-type: none"> - Field Blank - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - very light particle loading - Some sub-micron particles observed with the remainder of the population ranging from 1 to 20 μm
UN/FB/35	NA	Z5420	603736 (SEM)	UN Building, Kuwait	<ul style="list-style-type: none"> - Field Blank - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Very light particle loading
UN/FB/30	NA	Z5421	603737 (SEM)	UN Building, Kuwait	<ul style="list-style-type: none"> - Field Blank - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Very light particle loading
PS3/AS/39	12-13 Nov 1991	Z5644	603738 (SEM) 46328 (TEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light to moderate particle loading - Majority of particles sub-micron with remainder of population ranging from 1 to 10 μm
PS3/AS/51	13-14 Nov 1991	Z5645	603739 (SEM) 46333 20	I Saudi Arabia	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Moderate particle loading with particles ranging from sub-micron to 10 μm
PS3/AS/51	U-14 Nov 1991	Z5645	603739 (SEM) 46332 (TEM)	Khobar, Saudi Arabia	<ul style="list-style-type: none"> - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Moderate particle loading with particles ranging from sub-micron to 10 μm

TABLE G-2-68. IDENTIFICATION AND OBSERVATIONS OF AS-RECEIVED INDUSTRIAL HYGIENE SAMPLES COLLECTED ON 25 MM PC FILTERS IN KUWAIT AND SAUDI ARABIA

AEHA Field Sample No.	Date Collected	AEHA Lab No.	RJ Lee Group Sample No.	Sample Location Site	Observations/Comments
PS3/AS/61	14-15 Nov 1991	Z5646	603740 (SEMI) 49771 (TEM)	Khobar, Saudi Arabia	- Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Moderate particle loading with panicles ranging from sub-micron to 10 μ m
PS3/AS/40	15-16 Nov 1991	Z5647	603741 (SEM) 46329 (TEM)	Khobar, Saudi Arabia	- Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light to moderate particle loading - Majority of particles sub-micron with remainder of population ranging from 1 to 10 μ m
PS3/AS/72	16-17 Nov 1991	Z5648	603742 (SEM) 46345 (TEM)	Khobar, Saudi Arabia	- Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Moderate particle loading - Majority of particles ranging from 1 to 20 μ m with some sub micron particles observed
PS3/AS/71	18-19 Nov 1991	Z5649	603743 (SEM) 46344 (TEM)	Khobar, Saudi Arabia	- Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Moderate particle loading with particles ranging from sub-micron to 10 μ m
PS3/FB/62	NA	Z5650	603744 (SEM)	Khobar, Saudi Arabia	- Field Blank - Filter received on 11 Nov 1992 in two sections: 1/2 in the sample collection cassette and 1/2 taped to a plastic petri dish - Light particle loading

TABLE G-2-68. SUMMARY OF CCSEM/TEM AERODYNAMIC MASS DISTRIBUTION RESULTS FOR INDUSTRIAL HYGIENE SAMPLES COLLECTED ON PC FILTERS IN KUWAIT (WT. %)

AEHA Field Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	Particle Size Range (μm)				
				0.01-4	4-7.5	7.5-10	10-30	> 30
OF/AS/47	1 Nov 1991	Oil Fields	603705	10	39	17	34	—
OF/AS/48	1 Nov 1991	Oil Fields	603706	26	43	13	18	—
OF/AS/58	2 Nov 1991	oil Fields	603709	27	39	16	17	—
OF/AS/67						11		—
OF/AS/68	33 Nov 1991	Oil Fields	603713	5	29	16	59	—
OF/AS/42	4 Nov 1991	Oil Fields	603716	24	41		18	—
OF/AS/28				18		17		—
OF/AS/69	4 Nov 1991	Oil Fields	603717	13	39	13	43	25
OF/AS/70	5 Nov 1991	Oil Fields	603721	34	40	8	18	—
UN/AS/33			603724		30			—
UN/AS/38	6 Nov 1991	UN Building	603726	19	38	30	49	—
UN/AS/73	8 Nov 1991	UN Building	603728	15	31	13	22	—
UN/AS/65	9 Nov 1991	UN Building	603731	19	49	17	16	—
UN/AS/55	11 Nov 1991	UN Building	603733	14	36	15	35	—
UN/AS/37	12 Nov 1991	UN Building	603734	15	49	15	21	—
MH/AS/53	7 Nov 1991	Military Hospital	603725	12	43	21	24	—
MH/AS/63	8 Nov 1991	Military Hospital	603727	16	39	13	32	—
MH/AS/64	9 Nov 1991	Military Hospital	603729	27	39	16	18	—
MH/AS/54	11 Nov 1991	Military Hospital	603732	31	25	19	25	—

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TABLE O-2-70. SUMMARY OF CCSEM/TEM AERODYNAMIC MASS DISTRIBUTION RESULTS FOR INDUSTRIAL HYGIENE SAMPLES COLLECTED ON PC FILTERS IN SAUDI ARABIA (WT. %)

AEHA Rdd Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	Particle Size Range (μm)				
				0.01-4	4-7.5	7.5-10	10-30	> 30
PS3/AS/39	12 Nov 1991	Khobar Towers	603738	21	39	17	24	—
PS3/AS/51	13 Nov 1991	Khobar Towers	603739	38	32	13	17	—
PS3/AS/61	14 Nov 1991	Khobar Towers	603740	25	28	16	31	—
PS3/AS/40	15 Nov 1991	Khobar Towers	603741	22	37	17	24	—
PS3/AS/72	16 Nov 1991	Khobar Towers	603742	11	45	17	27	—
PS3/AS/71	18 Nov 1991	Khobar Towers	603743	15	35	23	26	—

TABLE O-2-71. SUMMARY OF CCSEM/TEM PARTICLE-TYPE DATA FOR INDUSTRIAL HYGIENE COLLECTED ON PC FILTERS IN KUWAIT

AEHA Field Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	Si-rich and Mixed Clays		Ca-rich		C-rich		Miscellaneous	
				Wt. %	# Part.	Wt. %	# Part.	Wt. %	# Part.	Wt. %	# Part.
OR/AS/47	1 Nov 1991	oil Fields	603705	52	92	39	62	5	31	4	17
OF/AS/48	1 Nov 1991	Oil Fields	603706	56	130	23	58	15	66	6	7
OF/AS/58	2 Nov 1991	Oil Fields	603709	54	131	24	37	19	34	4	18
OR/AS/67	3 Nov 1991	Oil Fields	603712	47	103	25	47	24	77	2	9
OF/AS/68	3 Nov 1991	Oil Fields	603713	51	113	41	80	6	54		7
OF/AS/42	4 Nov 1991	oil Fii	603716	52	123	31	85	14	32	3	8
OF/AS/28	4 Nov 1991	oil Fields	603717	56	77	34	51	8	22	2	5
OF/AS/69	4 Nov 1991	Oil Fields	603718	41	102	30	68	17	65	11	17
OF/AS/70	5 Nov 1991	Oil Fields	663721	31	81	31	70	33	86	5	15
UN/AS/33	6 Nov 1991	UN Building	603724	12	18	46	34	38	63	4	9
UN/AS/38	7 Nov 1991	UN Building	603726	47	113	31	75	13	51	8	21
UN/AS/73	8 Nov 1991	UN Building	603728	33	75	40	86	13	81	13	21
UN/AS/65	9 Nov 1991	UN Building	603731	40	80	30	52	23	86	7	
UN/AS/55	11 Nov 1991	UN Building	603733	39	103	32	67	25	55	4	21
UN/AS/37	12 Nov 1991	UN Building	603734	45	103	41	91	7	45	7	14
MH/AS/53	7 Nov 1991	Military Hospital	603725	45	98	41	92	8	51		16
MH/AS/63	8 Nov 1991	Military Hospital	603727	53	100	31	75	11	66	5	20
MH/AS/64	9 Nov 1991	Military Hospital	603729	34	54	30	72	27	76	9	18
MH/AS/54	11 Nov 1991	Military Hospital	603732	33	89	39	89	23	56	5	19

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TABLE G-2-72. SUMMARY OF CCSEM/TEM PARTICLE-TYPE DATA FOR INDUSTRIAL HYGIENE SAMPLES COLLECTED ON PC FILTERS IN SAUDI ARABIA

AEHA Field Sample No.	Date Collected	Sample Location Site	RJ Lee Group Sample No.	Si-rich and Mixed Clays		Ca-rich		C-rich		Miscellaneous	
				Wt. %	# Part.	Wt. %	# Part.	Wt. %	# Part.	Wt. %	# Part.
PS3/AS/39	12 Nov 1991	Khobar Towers	603738	24	51	35	78	28	117	11	26
PS3/AS/51	13 Nov 1991	Khobar Towers	603739	45	89	26	72	18	93	13	24
PS3/AS/6_1	14 Nov 1991	Khobar Towers	603740	36	100	44	114	17	54	3	5
PS3/AS/40	15 Nov 1991	Khobar Towers	603741	32	95	46	103	15	52	7	16
PS3/AS/72	16 Nov 1991	Khobar Towers	603742	34	67	56	115	7	31	3	9
PS3/AS/71	18 Nov 1991	Khobar Towers	603743	27	75	57	133	14	53	1	7

Fii Rpt, Kuwait Oil Fire HRA No. 39-26-L192-91, 5 May - 3 Dec 91

**FINAL REPORT
KUWAIT OIL FIRE HEALTH RISK ASSESSMENT NO. 39-26-L192-91
5 MAY - 3 DECEMBER 1991**

**APPENDIX H
RADIOLOGICAL ANALYSIS**

5 JAN 1994

MEMORANDUM FOR Chief, Health Risk Assessment Branch

SUBJECT: Evaluation of Additional Kuwait **HRA** Samples for Depleted Uranium (**DU**)

1. References:

- a. **Memorandum, USAEHA, HPD, HSHB-MR-HI, 13 July 1992, subject: Evaluation of Kuwait Air Samples for Radioactivity (enclosure 1).**
 - b. **Memorandum, USAEHA, HPD, HSHB-MR-HI, 6 August 1993, subject: Evaluation of Original Kuwait HRA Samples for Depleted Uranium (DU) (enclosure 2).**
 - c. **Memorandum, USAEHA, RAB, HSHB-ML-RR, 15 December 1993, subject: Results of Gross Alpha and Gross Beta Analyses of Kuwait Air Piltus, Project No. 27-22-E24K (enclosure 3).**
 - d. **Title 10, CFR, 1993 rev, Part: 20, Standards for Protection Against Radiation (U.S. Nuclear Regulatory Commission).**
 - e. **International Commission on Radiological Protection (ICRP) Report No. 23, Report of the Task Group on Reference Man, 1975.**
 - f. **CRC Handbook of Radiation Measurement and Protection, Section A, Volume II: Biological and Mathematical Information, copyright 1982 by CRC Press, Inc.**
 - g. **National Council on Radiation Protection and Measurements (NCRP) Report No. 95, Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources, 1987.**
2. **Purpose.** To provide a health physics evaluation of air filter samples collected in Kuwait and Saudi Arabia to assist in efforts in determining the **potential** health risks from oil well fires.
3. **General.**
- a. **The Air Pollution Engineering Division (APED) implemented an air sampling monitoring program to evaluate the potential health risks from oil well fires in Kuwait, Saudi Arabia, and their environment. An element of the health risk evaluation is to determine the concentration of natural radionuclides (and specifically DU) released into the air from the oil well fires'.**

HSMB-MR-HI

SUBJECT: Evaluation of Additional Kuwait HRA Samples for Depleted Uranium (DU)

b. The analysis and evaluation of the original air samples (reference 1a) for radionuclides did not include data from two areas of known troop concentrations (Camp Abdaly and the town of Doha, both in the Emirate of Kuwait) during Operation Desert Storm (reference 1b).

(1) Twenty-seven samples from Doha (from both Camp Thunder Rock and the UN Building sites) were selected and analyzed in order to complete the Health Risk Assessment.

(2) The two samples that were collected at Camp Abdaly could not be analyzed due to the lack of a known air volume drawn through the filters.

4. Air Filter Sample Evaluation.

a. The Radiochemistry Analysis Branch (RAB), Radiological and Inorganic Chemistry Division, received and analyzed 25 air filter samples collected in Doha. The air filter samples were collected by APED.

b. All air filter samples were analyzed for gross alpha and gross beta-g- activities per unit volume.

(1) The sample results were reviewed for the potential presence of DU. Since DU is an alpha emitter, any sample with an elevated alpha activity could be evaluated for the presence of DU. However, further isotopic analysis, in addition to the initial radionuclide screening, would be required to positively identify DU, through determination of percentages of abundance of the various isotopes within the uranium radioactive decay series,

(2) If an analysis of any sample had indicated activity statistically greater than the background samples (more than three times), then additional analysis, to include isotopic identification, would have been done. This condition was not met for any of the air filter samples evaluated either in this study or that in reference 1a.

c. Since these samples were collected concurrently with the group evaluated in reference 1a, the same background study (reference 1a, paragraph 4b) may be used for this current evaluation.

HSHB-MR-HI

SUBJECT: Evaluation of Additional Kuwait HRA Samples for Depleted Uranium (DU)

(1) The average background concentration for gross alpha radiation was measured to be 2.2×10^{-14} microcuries per milliliter ($\mu\text{Ci/ml}$) of air, with a sample range from 6.7×10^{-15} $\mu\text{Ci/ml}$ of air to 4.1×10^{-14} $\mu\text{Ci/ml}$ of air.

(2) The average background concentration for gross beta radiation was measured to be 3.7×10^{-14} $\mu\text{Ci/ml}$ of air for gross beta radiation, with a sample range from 1.2×10^{-14} $\mu\text{Ci/ml}$ of air to 6.0×10^{-14} $\mu\text{Ci/ml}$ of air.

d. The air filter samples were analyzed as per reference 1c (enclosure 3).

(1) Analyses showed that the average gross alpha activity was 3.1×10^{-14} $\mu\text{Ci/ml}$ of air. Gross alpha measurements ranged from 5.3×10^{-15} $\mu\text{Ci/ml}$ of air to 7.5×10^{-14} $\mu\text{Ci/ml}$ of air.

(2) The average gross beta was 3.6×10^{-14} $\mu\text{Ci/ml}$ of air. Gross beta measurements ranged from 4.8×10^{-15} $\mu\text{Ci/ml}$ of air to 5.6×10^{-14} $\mu\text{Ci/ml}$ of air.

(3) The average radionuclide concentrations of the samples were consistent with radionuclide concentrations measured in the designated samples collected for background determinations (average gross alpha radiation background of 2.2×10^{-14} $\mu\text{Ci/ml}$ and average gross beta-gamma of 3.7×10^{-14} $\mu\text{Ci/ml}$).

(4) The laboratory results of the air filter samples indicate no statistically significant differences between the background samples and the samples collected to measure the release of radioactivity into the air.

5. Exposure Assessment.

a. The average radionuclide concentrations obtained from the laboratory analyses of the air filter samples can be compared with those associated with the U.S. dose limit for individual members of the general public (i.e., reference 1d, paragraphs 20.1301 and 20.1302(b) (2), and Table 2, Appendix B of paragraphs 20.1001-20.2402).

(1) This dose limit (100 millirem/year total effective dose equivalent) and the associated radionuclide effluent concentration values are for the assessment and control of ionizing radiation exposure to members of the U.S. public.

HSMB-MR-HI

SUBJECT: Evaluation of Additional Kuwait HRA Samples for Depleted Uranium (DU)

(2) The annual average concentrations of radioactive material released in a **gaseous** effluent at the boundary of an unrestricted *area* must not exceed the values specified in Table 2 in order *to* comply with the dose limits *for* members of the general public.

(3) These concentration values are equivalent to radionuclide concentrations **which**, *if* inhaled continuously over the course of a year, would produce a Total Effective Dose Equivalent (TEDE) of 50 millirem.

(4) The concentration values for some radionuclides of interest are 6×10^{-14} $\mu\text{Ci/ml}$ for uranium-238, 6×10^{-14} $\mu\text{Ci/ml}$ for uranium-235, 5×10^{-14} $\mu\text{Ci/ml}$ for uranium-234, 6×10^{-10} $\mu\text{Ci/ml}$ for potassium-40, 9×10^{-11} $\mu\text{Ci/ml}$ for uranium-natural, 6×10^{-15} $\mu\text{Ci/ml}$ for thorium-232, and 1×10^{-10} $\mu\text{Ci/ml}$ for radon-222 plus decay products.

b. The gross radionuclide concentrations **measured** in the air filter samples are well below the radionuclide concentration values applicable to the U.S. **dose limit** for the general public. As a theoretical example, if the *average* air filter sample radionuclide concentration (gross alpha), 3.1×10^{-14} $\mu\text{Ci/ml}$, were all uranium-238 (DU is 99.7% uranium-238), and were inhaled continuously *for* a year, the Total Effective Dose Equivalent would be less than the dose limit for the general public, associated **with the** uranium-238 concentration value of 6×10^{-14} $\mu\text{Ci/ml}$ given in Table 2 of the reference.

6. Dose Assessment.

In order to assess the health risk associated with a *single radionuclide*, such as DU (99.7% uranium-238), a worst **case estimate** could assume (incorrectly) that **the entire** gross alpha and gross beta concentrations measured in the air filter samples are from DU. For such a theoretical scenario:

(1) In a single day, Reference **Man** (an internal **dosimetry** model used for dose calculations; see reference 1e) would inhale 2.68 micrograms of DU, which is a factor of 5.36 higher *than* the average daily airborne intake of 0.5 micrograms of uranium by Reference **Man** according to reference 1f, Table 5.5-45.

HSHB-FIR-HI

SUBJECT: Evaluation of Additional Kuwait HRA Samples for Depleted Uranium (DU)

(2) Even so, if Reference Man were to breathe these concentrations for an entire year, the **50-year Committed Effective Dose Equivalent** (whole body) would be 186 **microrem** (**extrapolated** from reference 1f, Table 6.4-11).

(3) According to U.S. radiation protection standards for non-radiation **workers**, individual **members** of the general public may receive 100 millirem (100,000 **microrem**) in any given year [reference 1d, paragraph 20.1301(a)(1)]. Therefore, the 50-year Committed Effective Dose Equivalent given above is extremely low (186 **microrem** or 0.186 millirem received over 50 years << 100 millirem/year).

(4) In perspective, a comparison between this **50-year Committed Effective Dose Equivalent** (whole body) of 186 **microrem** can be made with the **50-year Committed Dose Equivalent** (lung dose) of 100 **microrem** to 2000 **microrem** received by individuals (estimated population of 18,000,000) living within a 10-mile radius of thirty 1,000 MW, oil-combustion, electric generating stations in the United States (reference 1g).

7. Discussion.

a. It is understood that only two **air** samples were taken at Camp Abdaly due to the rapid departure of U.S. Forces. Since neither sample contained the necessary information to be analyzed, it is suggested that Camp Abdaly be removed from consideration in the Health Risk Assessment (at least from the radiological standpoint).

b. Average background levels were measured to be 2.2×10^{-14} $\mu\text{Ci/ml}$ of air for gross alpha radiation and 3.7×10^{-14} $\mu\text{Ci/ml}$ of air for gross beta radiation. Any dose assessments calculated using the measured radionuclide concentrations from the air filter samples are well below U.S. regulatory limits for the general public.

c. This evaluation does not apply to subgroups such as tank maintenance workers who prepared tanks with damaged DU shielding or injured soldiers with DU shrapnel in their bodies.

8. Conclusions.

a. No radiological health hazards can appear to be attributed to radioactive material detected on designated air filter samples from the APED air sampling monitoring program.

HSHB-HR-HI

SUBJECT: Evaluation of Additional Kuwait HRA Samples for Depleted Uranium (DU)

Laboratory analyses of the air filter **samples** indicate that alpha and beta-gamma activities, which also could suggest the presence of DU, *were* not significantly different from the alpha and beta-gamma activities detected *on* the **background** air filter samples.

b. **The** air filter sample analyses imply that the radiological health risk to the **DOD** population-at-large in Kuwait and Saudi Arabia from the oil well fires, with their resultant air **quality, was no greater** than that of a comparable nature, and within dose limits, to individuals of the general U.S. population.

9. Recommendations. None.

10. Points of **contact** are **Mr. David Alberth** and 1LT Robert **Friedman**, Ext. 3502.

3 Encls
as


HARRIS EDGE
Chief, Industrial Health Physics
Branch
Health Physics Branch

CF:
DRES
DLS
c, **HPD**
C, **MHPB**
c, **Tox**
C, **RAB**



13 JUL 1992

MEMORANDUM FOR Chief, Waste Disposal Engineering Division

SUBJECT: Evaluation of Kuwait Air Samples for Radioactivity

1. References:

a. Memorandum, USAEHA, HSHB-ME-S, 31 May 1991, subject: Request for Assistance.

b. Memorandum, USAEHA, HSHB-MR-H, 2 August 1991, subject: Radioactivity Released in Burning Petroleum in Kuwait.

c. Memorandum, USAEHA, HSHB-ML-RR, 18 March 1992, subject: Results of Gross Alpha and Gross Beta Analyses of Kuwait Air Filters, Project No. 38-26-K197 (enclosure 1 with attachment).

d. National Council on Radiation Protection and Measurements (NCRP) Report No. 95, 30 December 1987, Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources.

2. Purpose. The evaluation of air samples collected from the Republic of Kuwait was performed to assist in your efforts to determine the potential health hazards from oil well fires in the Republic of Kuwait.

3. General.

a. The Air Pollution Engineering Division implemented an air sampling monitoring program to evaluate the potential health hazards from oil well fires in the Republic of Kuwait and its environment. An element of the health hazard evaluation was to determine the concentration of natural radionuclides released into the air from oil well fires.

b. There is very little radiological environmental data available for estimating the concentrations of natural radionuclides from the combustion of oil in the Republic of Kuwait. However, fossil fuels (coal, oil and natural gas) as used by industry and the general public in United States of America, releases radionuclides as an unwanted byproduct which could lead to an unwanted radiation exposure to the general public and the environment. Generally, the radionuclides of concern are potassium-40 (K-40); the thorium series (Th); the uranium series (U); radon-222 (Rn), and lead-210 (Pb-210); however, specific radionuclide determination was not performed because the detected gross activities were too low to perform this procedure. Estimates of natural occurring radionuclides in the earth's crust have been made, however, the concentration of natural occurring radionuclides varies quite widely in nature. Geographic location and geological

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SUBJECT: Evaluation of Kuwait Air samples for Radioactivity

origin of soils as well as climatic, and hydrological history are important in this regard.

3. **Pathway Analysis.** As a result of the potential distribution of natural radionuclides within the Kuwait environment from oil well fires, the public could receive radiation exposure through inhalation, through external exposure from radioactive materials deposited in the ground, through resuspension of this material into the air, and through the movement of the deposited radioactive material within the terrestrial, aquatic and marine food chains. The air sample results indicate that only radiation exposure through inhalation should be considered for this evaluation-

4. **Air Sample Evaluation.**

a. **The Radiological Analysis Branch, Radiological and Inorganic Chemistry Division received and analyzed 174 air samples collected in the Republic of Kuwait-** The air samples were collected by the Air Pollution Engineering Division. All air samples were analyzed for gross alpha and gross beta-gamma activities per unit volume of air.

b. **The Air Pollution Engineering Division identified 45 air samples as background air samples; Background air samples were collected from Eskan Riyahd; KQMC; and Eskan Village.** All of the areas were upwind locations from the oil well fires. The average gross alpha activity for all background air samples was 2.2×10^{-14} microcuries per milliliter (uCi/ml) of air. The gross alpha activity for all background air samples ranged from a low of 6.7×10^{-15} uCi/ml of air to a high of 4.1×10^{-14} uCi/ml of air. The average gross beta-gamma activity for all background air samples was 3.7×10^{-14} uCi/ml of air. The gross beta-gamma activity for all background air samples ranged from a low of 1.2×10^{-14} uCi/ml of air to a high of 6.0×10^{-14} uCi/ml of air. Enclosure 1 has the results of all background air samples-

c. **The remaining 129 air samples were collected downwind in the smoke plume from the oil well fires.** All air samples were analyzed for gross alpha and gross beta-gamma activities. The average gross alpha activity for all air samples was 2.2×10^{-14} uCi/ml of air. The gross alpha activity for all air samples ranged from a low of 7.6×10^{-16} uCi/ml of air to a high of 5.7×10^{-14} uCi/ml of air. The average gross beta-gamma activity for all air samples was 4.1×10^{-14} uCi/ml of air. The gross beta-gamma activity for all air samples ranged from a low of 1.7×10^{-14} uCi/ml of air to a high of 8.0×10^{-14} uCi/ml of air. Enclosure 1 has the results of all downwind air samples.

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SUBJECT: Evaluation of Kuwait Air samples for Radioactivity

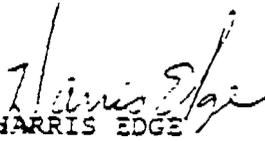
d. In general, the gross alpha and gross beta-gamma activities observed in the background air samples and the air samples collected in the smoke plume from oil well fires indicate that there is no significant differences between the two groups of air samples. The gross alpha and gross beta-gamma activities detected in air samples collected from the smokeplume of oil well fires are essentially natural background radiation. When we compare the release of natural radionuclides from oil well fires in Kuwait with the release of natural radionuclides in the United States environment, from the combustion of oil for the generation of electricity the radionuclide released in the United States appears to be higher (Reference paragraph 1d).

5. Conclusion. A review of the air sample data indicates that there is no radiological health hazards resulting from the oil well fires in the Republic of Kuwait.

6. Recommendations. None..

7. The point of contact for this evaluation is Hr. Allen Hilsmeier, exf. 3502/3526.

Encl
as


HARRIS EDGE
Chief, Industrial Health Physics
Branch
Health Physics Division



18 MAR 1992

MEMORANDUM FOR Chief, Health Physics Division (Mr. Hillsmeier)

SUBJECT: Results of Gross Alpha and Gross Beta Analyses of Kuwait Air Filters, Project No. 38-26-K197

1. Reference verbal conversation between Mr. Ronald Swatski, Mr. Steve Spence, Mr. Frances Soren, this office, and Mr. Allen Hillsmeier, HPD, on 31 Jan 92, subjects: Gross Alpha and Gross Beta Analyses of Kuwait Air Filters.
2. Gross alpha and gross beta analyses of 002 air filters from Kuwait are complete. The results of these analyses are listed in the enclosure.
3. The methodology employed in the air-filter analyses was an adaptation of our Gross Alpha and Gross Beta in Soil procedure. An aliquot of each air filter was counted for alpha and beta particles. Average alpha and beta filter background count rates were subtracted from the gross alpha and beta particle count rates. Then, alpha and beta counting efficiencies were assigned and alpha and beta activities calculated based on the volume of air that was drawn through the filter.
4. Average alpha and average beta filter background count rates were subtracted from each sample's gross alpha and gross beta count rates respectively. The average count rates for the filter backgrounds were determined by averaging several alpha and beta count rates of aliquots from unused filters, (filter #180, Wharman 1851-865) which had been provided by APED. These filter background aliquots were the same size, shape and area as the actual filter aliquots counted for each sample.
5. Alpha and beta counting efficiencies were based on the weight of particulate matter deposited on the filter aliquot. Basing the efficiencies on the particulate matter weight compensates for self-absorption in the particulate matter.
6. The particulate matter weight on the filter aliquot was calculated by multiplying the weight of particulate matter on the entire filter (from validated APED dBase files) by the percent of the filter counted. The percent of filter counted was determined by dividing the area of the filter aliquot by the filter's total active area (area over which particulate matter was deposited).

[Signature]
 Writer 3/17/92
 c. PAIB
 Log out 11:18 AM - 11
 3/17/92 - Jan
 Sent to Paul

HEHE-ME-RR

SUBJECT: Results of Gross Alpha and Gross Beta Analyses of
Kuwait Air Filters, Project No. 58-23-K197

7. Since several destructive analyses, such as metals analyses, had been performed on portions of each filter prior to its receiving the filters, we could not directly measure the size of the entire filter's active area. The entire filter's active area was estimated based on measurements of unused filters (filter 4400/Whatman 1331-9331). Based on these measurements, we estimated that the filters active areas were approximately 21.2 cm by 18 cm. If this estimation is inappropriate for any filter then the results listed in the enclosure for that filter are incorrect and must not be used. If necessary, results will be re-calculated after we are furnished with actual entire filter active areas.

8. Listed in the enclosure are filter information and results. Filter information was combined from validated APED data files, an MAB spreadsheet file, and RAB instrument files. The information was used to calculate the results listed in the enclosure.

9. Duplicate analyses were performed on approximately 10% of the filters. Two aliquots were analyzed from the same filter as described above. Results of duplicate filters are indicated in the enclosure by appending the suffix 'dup' to the laboratory number. The duplicate analysis is listed immediately following the original analysis. For example, laboratory numbers Y1661 and Y1660-dup refer to the original analysis and the duplicate analysis of Y1660, respectively.

10. Several filters were counted for which data did not exist in the APED files. Therefore, a filename does not appear in the 'APED DBS Filename' column of the enclosure. The volumes and weights of these filters are unknown and therefore, indicated with zeros in the 'Volume (m³)' and 'Weight (g)' columns, respectively. Results could not be calculated and are indicated in the various result columns by 'N/A'.

11. Results listed include the alpha lower limit of detection (Alpha LLD), beta lower limit of detection (Beta LLD), alpha activity (Alpha Act), alpha counting uncertainty at the 95% confidence interval (Alpha Unc), beta activity (Beta Act),

HEHE-VL-RR

SUBJECT: Results of Gross Alpha and Gross Beta Analyses of
Kuwait Air Filters, Project No. 88-26-K107

and beta counting uncertainty at the 95% confidence level
(Beta Unc). All results units are microcurie per milliliter of
air (uCi/ml).

12. All results listed in the enclosure have been reported to
two significant figures. This has been done to facilitate report
generation and eliminate manual transcriptions of the data.

13. The information reported in the enclosure is contained in a
dBase file. Therefore, if alternate report formats are necessary
please coordinate requirements with the contacts listed below.

14. Laboratory analyses were completed on 3 Feb 92. Additional
calculations were then requested by HPD. These additional
calculations involved non-routine data manipulations and
therefore, increased the laboratory report time.

15. Point of contact for additional information is
Mr. Ronald J. Swatski or Ms. Frances Scrom, extension 5-2612.

ORIGINAL SIGNED

Enc1

RONALD J. SWATSKI
Chief, Radiochemistry
Analysis Branch



Results of Analyzing Air Filter Samples

Lab Number	Filter Number	AFED DEF Filename	Installation (Area 402 etc)	Volume (ml)	Weight (g)	Alpha LLD (dCi/ml)	Beta LLD (dCi/ml)	Alpha Act (dCi/ml)	Alpha Unc (dCi/ml)	Beta Act (dCi/ml)	Beta Unc (dCi/ml)
Y1674	5248276	WASHVOL.DBF	Camp Freezco	1635.4	0.88756	2.5E-14	2.1E-14	2.5E-14	2.5E-14	5.1E-14	2.1E-14
Y1675	5248283	WASHVOL.DBF	Camp Freezco	1433.2	0.91457	2.7E-14	2.5E-14	2.5E-14	2.5E-14	5.1E-14	2.1E-14
Y1676	5248299	WASHVOL.DBF	Camp Freezco	1523.5	0.82255	2.7E-14	2.5E-14	4.5E-14	2.5E-14	5.5E-14	2.5E-14
Y1677	5248309	WASHVOL.DBF	Camp Freezco	1582.7	0.81708	2.6E-14	2.5E-14	2.5E-14	2.5E-14	5.5E-14	2.5E-14
Y1678	5248300		Camp Freezco	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y1679	5248304		Camp Freezco	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y1680	5248300		Camp Freezco	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y1681	5248195	WASHVOL.DBF	Al Khobar Towers	1557.1	0.92815	1.5E-14	2.1E-14	2.1E-14	2.1E-14	4.2E-14	2.1E-14
Y1682	5248203	WASHVOL.DBF	Al Khobar Towers	1575.0	0.91079	1.5E-14	2.1E-14	2.1E-14	2.1E-14	4.1E-14	2.1E-14
Y1683	5248209	WASHVOL.DBF	Camp 1	1775.5	0.93670	1.5E-14	2.1E-14	2.1E-14	2.1E-14	4.2E-14	2.1E-14
Y1684	5248249	WASHVOL.DBF	Camp 1	2071.0	0.91044	1.7E-14	2.1E-14	2.1E-14	2.1E-14	4.2E-14	2.1E-14
Y1685	5248248	WASHVOL.DBF	Camp 1	1775.0	0.93100	1.5E-14	2.1E-14	2.1E-14	2.1E-14	4.2E-14	2.1E-14
Y1686	5248244	WASHVOL.DBF	Al Khobar Towers	1708.0	0.82445	2.0E-14	1.9E-14	1.9E-14	1.9E-14	3.8E-14	2.1E-14
Y1687	5248244	WASHVOL.DBF	Camp 1	1692.7	0.91104	2.0E-14	2.0E-14	2.0E-14	2.0E-14	3.8E-14	2.1E-14
Y1688	5248240	WASHVOL.DBF	Al Khobar Towers	1845.0	0.45150	1.6E-14	1.7E-14	2.7E-14	1.9E-14	4.7E-14	2.5E-14
Y1689	5248242	WASHVOL.DBF	Camp 1	2041.2	0.45760	1.5E-14	1.6E-14	3.5E-14	2.1E-14	5.0E-14	2.5E-14
Y1690	5248242	WASHVOL.DBF	Al Khobar Towers	1848.0	0.55460	1.5E-14	1.6E-14	2.0E-14	2.1E-14	3.7E-14	2.1E-14
Y1691-242	5248240	WASHVOL.DBF	Al Khobar Towers	1845.0	0.92480	1.5E-14	1.6E-14	2.7E-14	1.6E-14	4.1E-14	2.1E-14
Y1691	5248244	WASHVOL.DBF	Al Khobar Towers	1792.0	0.97411	1.6E-14	1.6E-14	2.7E-14	1.9E-14	3.9E-14	2.1E-14
Y1692	5248201	WASHVOL.DBF	Camp 1	2204.5	0.97465	1.2E-14	1.4E-14	2.6E-14	1.6E-14	3.5E-14	2.1E-14
Y1693	5248210	WASHVOL.DBF	Camp 1	1839.5	0.91320	1.3E-14	1.5E-14	3.0E-14	1.6E-14	4.5E-14	2.5E-14
Y1694	5248204		Al Khobar Towers	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y1695	5248192		Al Khobar Towers	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y1696	5248192	WASHVOL.DBF	Al Khobar Towers	1810.0	0.95240	2.0E-14	2.0E-14	1.9E-14	1.9E-14	3.8E-14	2.1E-14
Y1696-242	5248192	WASHVOL.DBF	Al Khobar Towers	1810.0	0.95240	2.0E-14	2.0E-14	1.4E-14	1.9E-14	3.1E-14	2.1E-14
Y1697	5248192		Al Khobar Towers	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y1698	5248194		Al Khobar Towers	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y1699	5248201	WASHVOL.DBF	Camp 1	1844.7	0.90702	2.4E-14	2.1E-14	2.5E-14	1.7E-14	4.5E-14	2.1E-14
Y1700	5248200	WASHVOL.DBF	Camp 1	1833.2	0.90425	2.1E-14	1.8E-14	3.7E-14	3.0E-14	4.2E-14	2.5E-14
Y1701	5248197	WASHVOL.DBF	Al Khobar Towers	1811.0	2.17545	2.4E-14	1.9E-14	3.1E-14	4.1E-14	5.0E-14	2.1E-14
Y1702	5248194	WASHVOL.DBF	Al Khobar Towers	1751.0	0.95326	1.7E-14	1.9E-14	2.4E-14	1.9E-14	3.6E-14	2.1E-14
Y1703	5248207	WASHVOL.DBF	Camp 1	1811.0	0.92550	2.0E-14	1.7E-14	4.7E-14	2.6E-14	5.4E-14	2.5E-14
Y1703-242	5248207	WASHVOL.DBF	Camp 1	1811.0	0.92550	2.1E-14	1.7E-14	4.7E-14	2.6E-14	5.4E-14	2.5E-14
Y1704	5248205	WASHVOL.DBF	Camp 1	1875.0	1.15485	2.0E-14	1.8E-14	4.1E-14	2.3E-14	5.0E-14	2.7E-14
Y1705	5248208		Al Khobar Towers	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y1706	5248207	WASHVOL.DBF	Camp 1	2237.0	0.92050	1.7E-14	1.8E-14	2.3E-14	1.6E-14	3.4E-14	2.1E-14
Y1706-242	5248207	WASHVOL.DBF	Camp 1	2237.0	0.92050	1.7E-14	1.8E-14	2.7E-14	1.6E-14	3.4E-14	2.1E-14
Y1707	5248202	WASHVOL.DBF	Camp 1	1704.0	0.92020	1.7E-14	1.9E-14	2.0E-14	1.6E-14	4.0E-14	2.5E-14
Y1708	5248195	WASHVOL.DBF	Al Khobar Towers	2146.0	0.97414	1.4E-14	1.5E-14	2.1E-14	1.5E-14	4.2E-14	2.5E-14
Y1709	5248212	WASHVOL.DBF	Camp 1	2010.4	0.81475	2.0E-14	1.7E-14	4.9E-14	2.6E-14	5.4E-14	2.7E-14
Y1710	5248211	WASHVOL.DBF	Camp 1	1754.0	1.03592	2.6E-14	1.9E-14	2.9E-14	2.6E-14	5.2E-14	2.9E-14
Y1711	5248207	WASHVOL.DBF	Al Khobar Towers	1873.0	1.05250	2.4E-14	1.9E-14	1.7E-14	2.1E-14	3.1E-14	2.5E-14
Y1825	5248172	WASHVOL.DBF	Al Khobar Towers	1870.0	0.91943	1.5E-14	1.7E-14	2.3E-14	1.7E-14	3.6E-14	2.7E-14
Y1826	5248171	WASHVOL.DBF	Al Khobar Towers	2178.0	0.90942	1.6E-14	1.5E-14	2.0E-14	1.6E-14	3.5E-14	2.5E-14
Y1827	5248173	WASHVOL.DBF	Al Khobar Towers	1842.1	0.40305	1.5E-14	2.0E-14	1.5E-14	1.7E-14	3.6E-14	2.5E-14
Y1828	5248175	WASHVOL.DBF	Al Khobar Towers	1862.0	0.97712	1.6E-14	1.7E-14	5.6E-14	3.0E-14	4.1E-14	2.7E-14
Y1829	5248177	WASHVOL.DBF	Al Khobar Towers	2294.0	0.75000	1.6E-14	1.4E-14	1.6E-14	1.6E-14	4.1E-14	2.5E-14
Y1830	5248175	WASHVOL.DBF	Al Khobar Towers	1564.0	0.77920	1.9E-14	1.9E-14	1.9E-14	1.9E-14	4.2E-14	2.5E-14
Y1831	5248177	WASHVOL.DBF	Al Khobar Towers	2112.0	1.31004	2.2E-14	1.6E-14	2.2E-14	2.1E-14	4.6E-14	2.7E-14
Y1832	5248203	WASHVOL.DBF	Al Khobar Towers	1720.0	0.97940	1.9E-14	1.9E-14	1.9E-14	1.9E-14	3.8E-14	2.5E-14
Y1833	5248203	WASHVOL.DBF	Al Khobar Towers	1595.6	0.71150	2.7E-14	2.2E-14	1.9E-14	2.4E-14	2.4E-14	2.5E-14

Encl.

Results of Analyzing Air Filter Samples

Lab Number	Filter Number	AFSC DEF Filename	Installation (Area TAG es)	Volume (m ³)	Weight (g)	Alpha ULD (uCi/m ³)	Beta ULD (uCi/m ³)	Alpha Act (uCi/hr)	Alpha Inc (uCi/si)	Beta Act (uCi/hr)	Beta Inc (uCi/si)
Y1867	5207610	V08HIVOL.DBF	Camp 1	1089.1	1.34910	4.1E-14	2.0E-14	7.0E-15	2.0E-14	4.4E-14	2.0E-14
Y1868	5207624	V08HIVOL.DBF	Camp 1	1070.9	1.70325	1.0E-14	2.1E-14	1.0E-14	2.0E-14	2.1E-14	1.0E-14
Y1869	5207618	V08HIVOL.DBF	Al Khobar Towers	1820.0	1.40075	2.7E-14	1.0E-14	2.0E-14	2.0E-14	4.0E-14	1.0E-14
Y1870	5207619	V08HIVOL.DBF	Al Khobar Towers	2345.0	2.19466	1.6E-14	1.0E-14	4.1E-14	2.0E-14	3.0E-14	1.4E-14
Y1871	5207624	V08HIVOL.DBF	Al Khobar Towers	2045.0	0.83405	1.4E-14	1.4E-14	2.0E-14	2.0E-14	2.0E-14	1.4E-14
Y1871-dus	5207619	V08HIVOL.DBF	Al Khobar Towers	2045.0	0.83405	1.4E-14	1.4E-14	2.0E-14	2.0E-14	2.0E-14	1.4E-14
Y1872	5207617	V08HIVOL.DBF	Al Khobar Towers	1875.0	0.74170	1.6E-14	1.0E-14	2.0E-14	2.0E-14	4.0E-14	1.0E-14
Y1873	5207617	V08HIVOL.DBF	Camp 1	2010.9	0.47590	1.0E-14	1.0E-14	2.0E-14	2.0E-14	2.0E-14	1.0E-14
Y1874	5207620	V08HIVOL.DBF	Camp 1	1465.0	0.82230	2.1E-14	2.0E-14	2.0E-14	2.0E-14	2.0E-14	2.4E-14
Y1875	5207617	V08HIVOL.DBF	Al Khobar	1861.9	0.74064	1.6E-14	1.7E-14	1.0E-14	1.0E-14	2.0E-14	1.0E-14
Y1875	5207617	V08HIVOL.DBF	Camp Freedom	1865.9	2.30750	1.4E-14	1.0E-14	4.0E-14	4.0E-14	2.0E-14	2.0E-14
Y1875-dus	5207617	V08HIVOL.DBF	Camp Freedom	1865.9	2.30750	1.4E-14	1.0E-14	4.0E-14	4.0E-14	2.0E-14	2.0E-14
Y1876	5207615	V08HIVOL.DBF	Camp Freedom	1739.6	1.09573	2.4E-14	2.4E-14	2.0E-14	2.0E-14	6.0E-14	2.4E-14
Y1876	5207620	V08HIVOL.DBF	Military Hospital	1825.0	0.77768	1.7E-14	2.0E-14	1.0E-14	2.0E-14	2.0E-14	1.0E-14
Y1876	5207617	V08HIVOL.DBF	Military Hospital	1825.0	0.77768	1.7E-14	2.0E-14	1.0E-14	2.0E-14	2.0E-14	1.0E-14
Y1877	5207618	V08HIVOL.DBF	Military Hospital	1874.0	0.80542	2.0E-14	1.0E-14	2.0E-14	2.0E-14	2.0E-14	1.7E-14
Y1878	5207621	V08HIVOL.DBF	Military Hospital	1954.1	1.07852	2.9E-14	1.0E-14	2.4E-14	2.4E-14	4.0E-14	1.7E-14
Y1878	5207621	V08HIVOL.DBF	U.S. Embassy *	1473.7	0.77073	2.0E-14	2.0E-14	2.0E-14	2.0E-14	2.0E-14	2.0E-14
Y1880	5207620	V08HIVOL.DBF	U.S. Embassy *	1375.0	0.24067	2.0E-14	2.4E-14	2.0E-14	2.0E-14	2.0E-14	2.0E-14
Y1881	5207615	V08HIVOL.DBF	Military Hospital	2164.0	0.45326	1.6E-14	1.0E-14	2.0E-14	1.0E-14	2.0E-14	1.0E-14
Y1882	5207614	V08HIVOL.DBF	Military Hospital	1820.4	0.77043	1.9E-14	2.0E-14	1.0E-14	1.0E-14	2.0E-14	2.0E-14
Y1882-dus	5207614	V08HIVOL.DBF	Military Hospital	1820.4	0.77043	1.9E-14	2.0E-14	1.0E-14	1.0E-14	2.0E-14	2.0E-14
Y1881	5207614	V08HIVOL.DBF	Al Khobar	1911.0	0.75992	2.1E-14	1.7E-14	2.0E-14	2.0E-14	2.0E-14	1.0E-14
Y1881-dus	5207614	V08HIVOL.DBF	Al Khobar	1911.0	0.75992	2.1E-14	1.7E-14	2.0E-14	2.0E-14	2.0E-14	1.0E-14
Y1882	5207615	V08HIVOL.DBF	Al Khobar	1830.0	0.89933	1.6E-14	2.0E-14	4.0E-14	1.0E-14	2.0E-14	1.0E-14
Y1883	5207618	V08HIVOL.DBF	Al Khobar Towers	2075.0	1.07995	2.0E-14	1.0E-14	2.0E-14	2.0E-14	2.0E-14	1.0E-14
Y1884	5207618	V08HIVOL.DBF	Al Khobar Towers	1897.0	0.87877	2.2E-14	1.0E-14	2.4E-14	2.0E-14	2.0E-14	1.0E-14
Y1885	5207618	V08HIVOL.DBF	KMCO +	2045.0	1.07765	3.1E-14	1.7E-14	4.0E-14	2.0E-14	1.0E-14	1.0E-14
Y1886	5207618	V08HIVOL.DBF	KMCO +	1892.0	1.92220	4.0E-14	2.0E-14	3.4E-14	4.0E-14	2.0E-14	1.0E-14
Y1887	5207617	V08HIVOL.DBF	KMCO +	1733.7	0.85440	2.4E-14	1.7E-14	1.7E-14	2.0E-14	2.0E-14	1.0E-14
Y1888	5207618	V08HIVOL.DBF	KMCO +	1835.0	0.70901	2.4E-14	2.0E-14	1.0E-14	2.0E-14	2.0E-14	1.0E-14
Y1889	5207618	V08HIVOL.DBF	KMCO +	1770.0	0.74725	2.0E-14	1.0E-14	1.0E-14	1.0E-14	2.0E-14	1.0E-14
Y1890	5207618	V08HIVOL.DBF	KMCO +	1834.0	0.59420	2.0E-14	2.0E-14	3.4E-14	2.0E-14	2.0E-14	2.0E-14
Y1891	5207617	V08HIVOL.DBF	Camp Khobar	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y1892	5207617	V08HIVOL.DBF	U.S. Embassy *	1445.0	1.20732	1.4E-14	2.0E-14	4.0E-14	2.0E-14	2.0E-14	2.0E-14
Y1893	5207618	V08HIVOL.DBF	U.S. Embassy *	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y1894	5207618	V08HIVOL.DBF	U.S. Embassy *	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y1895	5207618	V08HIVOL.DBF	U.S. Embassy *	1742.0	0.20801	0.0E-14	2.1E-14	2.0E-14	4.0E-14	3.0E-14	1.9E-14
Y1896	5207617	V08HIVOL.DBF	Military Hospital	1471.0	2.28412	3.0E-14	2.4E-14	1.7E-14	3.0E-14	2.0E-14	1.0E-14
Y1897	5207618	V08HIVOL.DBF	Military Hospital	1732.0	1.16173	3.0E-14	2.1E-14	2.1E-14	4.0E-14	1.7E-14	1.0E-14
Y1898	5207618	V08HIVOL.DBF	Military Hospital	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y1899	5207618	V08HIVOL.DBF	Military Hospital	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y1900	5207616	V08HIVOL.DBF	Military Hospital	2045.0	1.48226	3.0E-14	1.7E-14	2.0E-14	2.0E-14	5.0E-14	1.0E-14
Y1901	5207618	V08HIVOL.DBF	Military Hospital	1870.0	0.84235	2.6E-14	2.1E-14	3.7E-14	2.0E-14	3.1E-14	2.1E-14
Y1901-dus	5207618	V08HIVOL.DBF	Military Hospital	1870.0	0.84235	2.6E-14	2.1E-14	2.0E-14	2.0E-14	4.0E-14	2.0E-14
Y1902	5207617	V08HIVOL.DBF	Al Khobar Towers	1740.0	2.05572	4.4E-14	2.0E-14	3.7E-14	4.0E-14	1.0E-14	1.0E-14
Y1903	5207618	V08HIVOL.DBF	Al Khobar	1874.0	2.74405	5.4E-14	2.0E-14	6.7E-14	3.0E-14	3.0E-14	1.0E-14
Y1904	5207618	V08HIVOL.DBF	Al Khobar	1370.0	2.78331	6.4E-14	2.0E-14	2.0E-14	4.0E-14	3.0E-14	2.0E-14
Y1905	5207618	V08HIVOL.DBF	Al Khobar Towers	1905.0	0.39554	1.7E-14	1.7E-14	1.6E-14	5.0E-14	1.0E-14	1.0E-14
Y1906	5207617	V08HIVOL.DBF	Al Khobar Towers	2045.0	0.37714	1.9E-14	1.0E-14	2.1E-14	1.0E-14	4.0E-14	1.0E-14
Y1907	5207618	V08HIVOL.DBF	Al Khobar	1859.0	0.75614	2.1E-14	1.0E-14	1.0E-14	1.0E-14	4.0E-14	1.0E-14

Results of Analyzing Air Filter Samples

Lab Number	Filter Number	AFSD 08F Filtrage	Installation (from TAB set)	Volume (m ³)	Weight (g)	Alpha UG/m ³	Beta UG/m ³	Alpha Act (dpci/m ³)	Alpha Unc (dpci/m ³)	Beta Act (dpci/m ³)	Beta Unc (dpci/m ³)
Y0125	5022041	VOEHIVOL.08F	Al Khobar Towers	1444.0	1.04512	2.1E-14	2.7E-14	3.1E-14	3.7E-14	4.0E-14	2.1E-14
Y0125-duo	5022041	VOEHIVOL.08F	Al Khobar Towers	1444.0	1.04510	2.1E-14	2.7E-14	2.8E-14	2.8E-14	4.8E-14	2.1E-14
Y0119	5022042	VOEHIVOL.08F	Al Khobar Towers	1744.5	0.35009	1.3E-14	1.7E-14	4.7E-15	1.3E-14	4.8E-14	1.7E-14
Y0119	5022042	VOEHIVOL.08F	Al Khobar Towers	1731.7	0.21183	1.7E-14	1.8E-14	2.3E-14	1.9E-14	4.1E-14	1.8E-14
Y0120	5022043	VOEHIVOL.08F	Al Khobar Towers	1735.0	0.22376	1.7E-14	1.8E-14	2.4E-14	1.8E-14	4.1E-14	1.8E-14
Y0121	5022044	VOEHIVOL.08F	Al Khobar Towers	2136.0	0.47102	1.8E-14	1.8E-14	2.2E-14	1.8E-14	4.1E-14	1.8E-14
Y0122	5022045	VOEHIVOL.08F	Al Khobar Towers	2131.0	0.37157	1.7E-14	1.8E-14	7.3E-15	1.4E-14	2.8E-14	1.4E-14
Y0123	5022046	VOEHIVOL.08F	Al Khobar Towers	1732.0	0.21659	1.4E-14	1.9E-14	2.1E-14	1.7E-14	2.3E-14	1.4E-14
Y0124	5022047	VOEHIVOL.08F	Al Khobar Towers	1721.7	0.24734	1.3E-14	1.8E-14	4.8E-15	1.3E-14	2.7E-14	1.7E-14
Y0125	5022048	VOEHIVOL.08F	Al Khobar Towers	1735.5	0.22322	1.3E-14	1.8E-14	4.8E-15	1.3E-14	2.6E-14	1.3E-14
Y0125-duo	5022048	VOEHIVOL.08F	Al Khobar Towers	1736.0	0.22322	1.3E-14	1.8E-14	2.8E-14	1.8E-14	2.8E-14	1.3E-14
Y0126	5022049	VOEHIVOL.08F	Al Khobar Towers	1849.0	0.44030	1.8E-14	1.7E-14	1.7E-14	1.8E-14	2.7E-14	1.8E-14
Y0127	5022050	VOEHIVOL.08F	Al Khobar Towers	2127.0	1.10787	1.8E-14	1.8E-14	2.2E-14	1.7E-14	4.5E-14	1.8E-14
Y0128	5022051	VOEHIVOL.08F	KKMC +	1877.0	0.77946	1.8E-14	1.7E-14	3.0E-14	2.2E-14	2.7E-14	1.8E-14
Y0128-duo	5022051	VOEHIVOL.08F	KKMC +	1877.0	0.77946	1.8E-14	1.7E-14	1.8E-14	1.7E-14	4.2E-14	1.7E-14
Y0129	5022052	VOEHIVOL.08F	KKMC +	2531.1	0.68971	1.1E-14	1.2E-14	1.8E-14	1.0E-14	3.1E-14	1.0E-14
Y0130	5022053	VOEHIVOL.08F	KKMC +	1760.5	0.45612	1.3E-14	1.8E-14	1.4E-14	1.4E-14	4.0E-14	1.3E-14
Y0131	5022054	VOEHIVOL.08F	KKMC +	2477.9	0.41693	1.1E-14	1.2E-14	2.1E-14	1.3E-14	2.7E-14	1.3E-14
Y0132	5022055	VOEHIVOL.08F	KKMC +	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0133	5022056	VOEHIVOL.08F	KKMC +	1883.5	0.35462	1.3E-14	1.7E-14	1.7E-14	1.7E-14	4.3E-14	1.3E-14
Y0134	5022057	VOEHIVOL.08F	KKMC +	1881.1	0.74923	1.5E-14	1.7E-14	2.6E-14	1.9E-14	4.3E-14	1.7E-14
Y0135	5022058	VOEHIVOL.08F	KKMC +	2532.6	0.45917	1.1E-14	1.3E-14	1.9E-14	1.9E-14	3.2E-14	1.1E-14
Y0136	5022059	VOEHIVOL.08F	Al Khobar Towers	2443.0	0.50374	1.3E-14	1.3E-14	1.8E-14	1.8E-14	3.1E-14	1.3E-14
Y0137	5022060	VOEHIVOL.08F	Al Khobar Towers	1819.0	0.50788	1.3E-14	2.1E-14	9.8E-15	1.8E-14	3.0E-14	1.3E-14
Y0138	5022061	VOEHIVOL.08F	Al Khobar Towers	1711.2	0.24500	1.6E-14	1.7E-14	1.3E-14	1.8E-14	4.2E-14	1.8E-14
Y0139	5022062	VOEHIVOL.08F	Al Khobar Towers	1940.0	0.22355	1.3E-14	1.7E-14	3.1E-15	1.8E-14	4.1E-14	1.7E-14
Y0139	5022062	VOEHIVOL.08F	Military Hospital	2024.2	1.01691	2.0E-14	1.8E-14	1.7E-14	1.9E-14	3.3E-14	1.8E-14
Y0140	5022063	VOEHIVOL.08F	U.S. Embassy *	1845.0	0.58750	2.0E-14	2.1E-14	3.0E-14	2.4E-14	4.8E-14	2.0E-14
Y0141	5022064	VOEHIVOL.08F	U.S. Embassy *	1413.0	0.55335	2.6E-14	2.3E-14	1.0E-14	2.0E-14	3.8E-14	2.6E-14
Y0142	5022065	VOEHIVOL.08F	U.S. Embassy *	1894.0	0.40005	2.2E-14	2.1E-14	2.1E-14	2.0E-14	2.4E-14	1.9E-14
Y0143	5022066	VOEHIVOL.08F	U.S. Embassy *	1897.7	0.75304	2.8E-14	2.1E-14	1.7E-14	2.1E-14	3.8E-14	1.9E-14
Y0144	5022067	VOEHIVOL.08F	Military Hospital	1404.7	0.15868	2.1E-14	2.3E-14	1.8E-14	1.8E-14	2.6E-14	2.0E-14
Y0145	5022068	VOEHIVOL.08F	Military Hospital	1877.7	0.38542	1.7E-14	1.7E-14	3.5E-15	1.4E-14	3.1E-14	1.6E-14
Y0146	5022069	VOEHIVOL.08F	U.S. Embassy *	1811.1	0.32300	1.3E-14	1.3E-14	7.7E-15	1.4E-14	2.4E-14	1.3E-14
Y0147-duo	5022069	VOEHIVOL.08F	U.S. Embassy *	1811.1	0.32300	1.3E-14	1.3E-14	1.8E-14	1.8E-14	2.9E-14	1.3E-14
Y0148	5022070	VOEHIVOL.08F	U.S. Embassy *	1745.3	0.21674	1.7E-14	1.8E-14	1.4E-14	1.8E-14	3.3E-14	1.7E-14
Y0149	5022071	VOEHIVOL.08F	Military Hospital	1573.2	0.74772	2.0E-14	2.1E-14	1.7E-14	1.8E-14	3.6E-14	2.1E-14
Y0150	5022072	VOEHIVOL.08F	Military Hospital	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0151	5022073	VOEHIVOL.08F	U.S. Embassy *	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0152	5022074	VOEHIVOL.08F	U.S. Embassy *	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0153	5022075	VOEHIVOL.08F	U.S. Embassy *	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0154	5022076	VOEHIVOL.08F	U.S. Embassy *	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0155	5022077	VOEHIVOL.08F	U.S. Embassy *	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0156	5022078	VOEHIVOL.08F	U.S. Embassy *	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0157	5022079	VOEHIVOL.08F	U.S. Embassy *	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0158	5022080	VOEHIVOL.08F	Military Hospital	1573.0	0.29171	2.0E-14	2.1E-14	1.4E-14	1.7E-14	3.1E-14	1.8E-14
Y0159	5022081	VOEHIVOL.08F	Military Hospital	1573.8	0.59235	1.8E-14	1.7E-14	1.0E-14	1.8E-14	2.5E-14	1.4E-14
Y0160	5022082	VOEHIVOL.08F	U.S. Embassy *	1827.3	1.05577	3.0E-14	2.3E-14	2.1E-14	2.6E-14	4.7E-14	2.1E-14
Y0161	5022083	VOEHIVOL.08F	KKMC +	1511.3	0.23061	1.7E-14	1.8E-14	2.9E-14	2.3E-14	3.9E-14	1.8E-14
Y0162	5022084	VOEHIVOL.08F	KKMC +	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0163	5022085	VOEHIVOL.08F	KKMC +	1743.0	1.26210	2.8E-14	1.9E-14	2.0E-14	3.5E-14	5.4E-14	2.0E-14
Y0164	5022086	VOEHIVOL.08F	KKMC +	2400.2	1.21271	2.0E-14	1.4E-14	4.0E-14	2.4E-14	3.6E-14	1.4E-14
Y0165-duo	5022086	VOEHIVOL.08F	KKMC +	2420.1	1.21271	2.0E-14	1.4E-14	2.6E-14	2.1E-14	2.7E-14	1.3E-14
Y0166	5022087	VOEHIVOL.08F	KKMC +	1921.3	0.34793	1.7E-14	1.7E-14	1.2E-14	1.4E-14	4.2E-14	1.7E-14

Results of Analyzing Air Filter Samples

Lab Number	Filter Number	AFSS DEF Filename	Installation (from MAB ss)	Volume (m ³)	Weight (g)	Alpha L15 (uCi/ml)	Beta L15 (uCi/ml)	Alpha Act (uCi/ml)	Alpha Unc (uCi/ml)	Beta Act (uCi/ml)	Beta Unc (uCi/ml)
Y0789	5000000		KKMC +	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0790	5000001	V04HIVOL.DBF	KKMC +	2000.8	0.35763	1.5E-14	1.5E-14	1.5E-14	1.5E-14	2.7E-14	1.5E-14
Y0791	5000002		KKMC +	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0101	5007463	V04HIVOL.DBF	Eskan, Riyand	2587.1	0.45310	1.1E-14	1.5E-14	3.0E-14	1.7E-14	3.0E-14	1.7E-14
Y0102	5007464	V04HIVOL.DBF	Eskan, Riyand	2584.0	0.25345	1.5E-14	1.7E-14	1.5E-14	1.5E-14	3.0E-14	1.5E-14
Y0103	5007465	V04HIVOL.DBF	Eskan, Riyand	2487.4	1.06542	1.4E-14	1.5E-14	3.0E-14	1.5E-14	3.0E-14	1.4E-14
Y0104	5007466	V04HIVOL.DBF	Eskan, Riyand	2521.9	1.54574	1.6E-14	1.7E-14	3.1E-14	3.0E-14	3.0E-14	1.7E-14
Y0105	5048100	V04HIVOL.DBF	Jubail	1549.0	0.37109	1.7E-14	2.1E-14	2.0E-14	2.0E-14	3.0E-14	1.7E-14
Y0106	5007467	V04HIVOL.DBF	Jubail	1535.8	0.28229	1.4E-14	2.0E-14	1.5E-14	1.4E-14	3.0E-14	1.7E-14
Y0107-100	5007467	V04HIVOL.DBF	Jubail	1535.8	0.24255	1.4E-14	2.1E-14	1.7E-14	1.7E-14	3.0E-14	1.7E-14
Y0107	5007468	V04HIVOL.DBF	Jubail	1707.5	0.32004	1.5E-14	1.9E-14	1.7E-14	1.7E-14	3.0E-14	1.6E-14
Y0108	5000019	V04HIVOL.DBF	Al Khobar	2097.0	0.27324	1.5E-14	1.5E-14	2.5E-14	1.7E-14	4.0E-14	1.7E-14
Y0109	5000019	V04HIVOL.DBF	Al Khobar	1741.0	0.25450	1.5E-14	1.8E-14	2.5E-14	1.9E-14	4.0E-14	2.0E-14
Y0110	5048200	V04HIVOL.DBF	Al Khobar	2488.0	0.54255	7.3E-15	1.2E-14	1.1E-14	1.1E-14	3.0E-14	1.2E-14
Y0111	5007469	V04HIVOL.DBF	Al Khobar	1958.0	0.29070	1.2E-14	1.6E-14	2.0E-14	1.5E-14	4.0E-14	1.7E-14
Y0112	5007467	V04HIVOL.DBF	Jubail	1838.5	0.77790	1.6E-14	1.7E-14	1.8E-14	1.8E-14	4.0E-14	1.8E-14
Y0113	5000037	V04HIVOL.DBF	KKMC +	1918.0	0.22471	1.2E-14	1.7E-14	5.7E-15	1.1E-14	7.4E-14	1.6E-14
Y0114	5000036	V04HIVOL.DBF	KKMC +	2724.8	0.27979	3.3E-15	1.3E-14	6.0E-15	6.0E-15	3.0E-14	1.3E-14
Y0115	5000035	V04HIVOL.DBF	KKMC +	2646.5	0.40070	9.2E-15	1.2E-14	1.6E-14	1.2E-14	3.0E-14	1.3E-14
Y0115-100	5000035	V04HIVOL.DBF	KKMC +	2646.5	0.40070	9.2E-15	1.2E-14	1.2E-14	1.1E-14	3.0E-14	1.3E-14
Y0116	5000034	V04HIVOL.DBF	KKMC +	1910.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0117	5000032	V04HIVOL.DBF	KKMC +	2530.5	1.21510	1.4E-14	1.3E-14	2.7E-14	1.7E-14	4.0E-14	1.7E-14
Y0118	5000033	V04HIVOL.DBF	KKMC +	1754.5	1.21330	2.1E-14	1.9E-14	3.6E-14	2.6E-14	4.4E-14	1.9E-14
Y0119	5000031	V04HIVOL.DBF	KKMC +	2711.7	0.79370	1.1E-14	1.2E-14	1.2E-14	1.2E-14	2.5E-14	1.2E-14
Y0120	5000030	V04HIVOL.DBF	KKMC +	1917.4	0.31244	1.6E-14	1.7E-14	5.0E-15	1.2E-14	4.4E-14	1.7E-14
Y0121	5007544	V04HIVOL.DBF	Jubail	1847.8	1.31322	2.0E-14	3.5E-14	1.7E-14	2.0E-14	3.4E-14	1.7E-14
Y0122	5000145	V04HIVOL.DBF	Military Hosp	1539.0	0.47105	1.6E-14	2.0E-14	3.0E-14	3.0E-14	3.0E-14	1.9E-14
Y0124	5000146	V04HIVOL.DBF	Military Hosp	2003.5	1.00770	1.7E-14	1.6E-14	3.1E-14	1.7E-14	3.1E-14	1.8E-14
Y0125	5000148	V04HIVOL.DBF	US Embassy *	1521.5	0.39770	1.6E-14	2.1E-14	2.1E-14	1.9E-14	5.4E-14	2.0E-14
Y0126	5000147	V04HIVOL.DBF	US Embassy *	1530.7	0.48810	1.6E-14	2.1E-14	3.2E-14	2.3E-14	4.1E-14	2.0E-14
Y0127	5000145	V04HIVOL.DBF	Military Hosp	1952.7	0.43249	1.4E-14	1.6E-14	2.0E-14	1.8E-14	6.0E-14	1.9E-14
Y0128	5000144	V04HIVOL.DBF	Military Hosp	1603.4	0.34424	1.5E-14	2.0E-14	2.0E-14	1.8E-14	4.7E-14	2.0E-14
Y0129	5000143	V04HIVOL.DBF	US Embassy *	1495.7	0.34600	1.4E-14	1.9E-14	1.9E-14	1.6E-14	3.5E-14	1.6E-14
Y0130	5000142	V04HIVOL.DBF	US Embassy *	1577.0	0.29709	1.5E-14	2.0E-14	2.7E-14	1.4E-14	3.0E-14	2.0E-14
Y0131	5000141	V04HIVOL.DBF	Military Hosp	1640.9	0.25300	1.4E-14	1.9E-14	1.3E-14	1.4E-14	4.7E-14	2.0E-14
Y0132	5000140	V04HIVOL.DBF	Military Hosp	2055.1	0.30300	1.3E-14	1.6E-14	1.4E-14	1.4E-14	3.7E-14	1.6E-14
Y0133	5000140	V04HIVOL.DBF	US Embassy *	1516.9	0.27699	1.0E-14	2.1E-14	2.1E-14	2.0E-14	2.6E-14	1.8E-14
Y0134	5000139	V04HIVOL.DBF	US Embassy *	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0134-100	5000139	V04HIVOL.DBF	US Embassy *	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0369	5007470	V04HIVOL.DBF	Eskan Village <	1700.4	0.27820	1.8E-14	1.7E-14	1.0E-14	1.5E-14	4.5E-14	1.9E-14
Y0370	5007469	V04HIVOL.DBF	Eskan Village <	2536.5	0.92915	1.2E-14	1.3E-14	2.4E-14	1.7E-14	3.5E-14	1.4E-14
Y0371	5007471	V04HIVOL.DBF	Eskan Village <	2714.9	0.74239	1.1E-14	1.2E-14	1.2E-14	1.2E-14	4.1E-14	1.4E-14
Y0372	5009645	V04HIVOL.DBF	Abu Dhabi	1952.9	0.93379	1.6E-14	1.7E-14	2.8E-14	2.1E-14	4.6E-14	1.5E-14
Y0373	5009646	V04HIVOL.DBF	Abu Dhabi	1774.2	1.03427	1.9E-14	1.8E-14	2.6E-14	2.2E-14	3.1E-14	1.7E-14
Y0374	5009641	V04HIVOL.DBF	Abu Dhabi	1515.0	1.99730	2.6E-14	1.8E-14	3.5E-14	3.0E-14	4.4E-14	1.9E-14
Y0375	5048131	V04HIVOL.DBF	Abu Dhabi	2073.5	0.75455	1.4E-14	1.6E-14	2.2E-14	1.7E-14	4.2E-14	1.6E-14
Y0376	5048132	V04HIVOL.DBF	Abu Dhabi	2252.5	0.42260	1.2E-14	1.4E-14	2.0E-14	1.6E-14	6.6E-14	1.8E-14
Y0376-100	5048132	V04HIVOL.DBF	Abu Dhabi	2252.5	0.42260	1.2E-14	1.4E-14	2.0E-14	1.6E-14	6.6E-14	1.8E-14
Y0377	5009642	V04HIVOL.DBF	Abu Dhabi	1775.0	1.26314	2.1E-14	1.9E-14	3.2E-14	2.5E-14	3.9E-14	1.9E-14
Y0755	5007474	V04HIVOL.DBF	Eskan Village <	1658.8	0.61518	1.6E-14	1.7E-14	4.1E-14	2.5E-14	4.9E-14	2.0E-14
Y0756	5007475	V04HIVOL.DBF	Eskan Village <	2630.0	1.19632	1.4E-14	1.2E-14	3.7E-14	2.1E-14	3.6E-14	1.4E-14

Results of Analyzing Air Filter Samples

Lab Number	Filter Number	AFED CSR Filename	Installation (From MAB list)	Volume (m ³)	Weight (g)	Alpha L10 (uCi/gal)	Beta L10 (uCi/gal)	Alpha Act (uCi/gal)	Alpha Unc (uCi/gal)	Beta Act (uCi/gal)	Beta Unc (uCi/gal)
Y0757	5207476	VO4HIVOL.DSF	Eskan Village <	1741.1	0.46558	1.2E-14	1.2E-14	7.1E-14	2.0E-14	4.4E-14	1.7E-14
Y0758	5207477	VO4HIVOL.DSF	Eskan Village <	2747.0	0.56156	1.2E-14	1.2E-14	3.9E-14	1.0E-14	4.2E-14	1.4E-14
Y0777	5207478	VO4HIVOL.DSF	Eskan Village <	1649.0	0.27135	1.4E-14	1.5E-14	1.8E-14	1.5E-14	4.1E-14	1.9E-14
Y0740	5207477		Eskan Village <	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0740-duc	5207478		Eskan Village <	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0741	5207480	VO4HIVOL.DSF	Eskan Village <	3191.2	0.57176	1.2E-14	1.2E-14	2.1E-14	1.6E-14	7.4E-14	1.2E-14
Y0742	5207481	VO4HIVOL.DSF	Eskan Village <	1648.8	0.35761	1.4E-14	1.5E-14	1.8E-14	1.5E-14	3.9E-14	1.8E-14
Y0743	5200081		KKMC +	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0744	5200081	VO2HIVOL.DSF	KKMC +	1924.4	0.31672	1.2E-14	1.2E-14	1.7E-14	1.6E-14	1.3E-14	1.2E-14
Y0745	5200084		KKMC +	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0746	5200083	VO2HIVOL.DSF	KKMC +	1910.0	0.47090	1.2E-14	1.2E-14	2.0E-14	1.7E-14	1.7E-14	1.2E-14
Y0747	5200085	VO2HIVOL.DSF	KKMC +	1738.4	0.56248	1.4E-14	1.7E-14	1.8E-14	1.6E-14	1.7E-14	1.7E-14
Y0748	5200085	VO2HIVOL.DSF	KKMC +	2685.7	0.52127	1.7E-14	1.2E-14	2.2E-14	1.4E-14	1.9E-14	1.2E-14
Y0749	5200087	VO2HIVOL.DSF	KKMC +	1655.0	0.40490	1.2E-14	1.7E-14	1.2E-14	1.7E-14	1.4E-14	1.6E-14
Y0750	5200086		KKMC +	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR
Y0751	5200086	VO2HIVOL.DSF	KKMC +	1871.0	0.32464	1.2E-14	1.7E-14	1.4E-14	1.7E-14	1.7E-14	1.2E-14
Y0752	5200089		KKMC +	0.0	0.00000	ERR	ERR	ERR	ERR	ERR	ERR

Legend

- + KKMC
- o Military Hospital
- Jubail
- ~~at Jubail~~
- At Khabar
- { Camp Freedom
- camp 1
- * US Embassy
- ~ Camp Abdaly
- Eskan, Riyadh
- < " Village



6 AUG 1993

MEMORANDUM FOR Chief, Health Risk Assessment Branch

SUBJECT: Evaluation of Original Kuwait HRA Samples for Depleted Uranium (DU)

1. References:

a. Memorandum, HSHB-MR-HI, USAEHA, 21 July 1993, subject: Request for Depleted Uranium (DU) Sampling Criteria for Kuwait Oil Fires Health Risk Assessment Team.

b. Memorandum, HSHB-MR-HI, USAEHA, 12 July 1992, subject: Evaluation of Kuwait Air Samples for Radioactivity.

2. Analysis and evaluation of 190 air samples out of approximately 1000 applicable samples (e.g., PM: particle size < 10 microns in-diameter) collected by the USAEHA Team were analyzed for gross alpha and beta radioactive contamination, but not specifically for DU. DU is primarily an alpha emitter and would have been detected in such analyses. No radioactivity above background levels was detected. There was no significant difference between the average concentrations of radioactivity from samples taken upwind from those taken downwind.

3. The 190 selected air samples were analyzed in March 1992. In reviewing the data by sampling location, since air samplers were placed where the troop concentrations were, the following information was obtained:

<u># Samples</u>	<u>Location</u>	<u># Samples</u>	<u>Location</u>
41	Al Khobar	0	Camp Abdaly
7	Camp Freedom	4	Eskan Rihahd
21	camp 1	10	Eskan Village
27	Al Jubail	0	Camp Thunder-
6	Jubail		rock (Doha)
24	Military Hospital		
33	KKMC		
17	U.S. Embassy		
		<u>190</u>	Total Samples

Encl 2

HSHB-MR-HI

SUBJECT: Evaluation of Original Kuwait HRA Samples for Depleted Uranium (DU)

4. In order to utilize the available air **sampling data** by troop location to address the risk of ionizing radiation from the Kuwait oil fires for the Health Risk Assessment, either the Camp Abdaly and Camp Thunderrock locations should **be** deleted or more samples should be counted from these two locations.

5. It is understood that limited sampling was done at Camp Abdaly due to the rapid departure of U.S. Forces; however, over 120 air samples were collected at Camp Thunderrock (Doha). The Health Physics Division recommends that, if these sites are to be included in the BRA, more samples from Camp Abdaly be counted and approximately **30-40** more samples from Camp Thunderrock be counted. To be consistent with the analyses already completed these extra samples should be counted for gross alpha/gross beta contamination. Discussion- **with** the Chief, Radiochemistry Analysis Branch, RICD, DLS, indicates that this in-house analysis **will** cost approximately \$1,465 and take approximately 2 months to provide laboratory analysis results to the Health Physics Division. If isotopic uranium analysis is performed (this is not the recommended option) on all of the samples previously analyzed, use of an outside contractor will be necessary. By using an outside contractor, it will cost \$22,500 and take approximately 6 - 12 months.

6. Our basic conclusion for the Kuwait Health Assessment Report remains: **"No** radioactive contamination above background levels was detected in the air samples analyzed for gross alpha and beta radiation, which would include radiation from DU. There was no significant difference between the average of concentrations taken upwind from those taken downwind." Average background levels were measured to be 2.2×10^{-14} **microcuries** per milliliter of air for gross alpha and 3.7×10^{-14} **microcuries** per milliliter in air *for* gross beta radiations, which is well below regulatory **concern**. There was negligible risk to the DOD **population-at-large** in Kuwait from any ionizing radiation risk due to the oil fires. This does not apply to **subgroups** such as tank maintenance workers who prepared tanks with damaged DU shielding or soldiers injured with DU shrapnel in their bodies.

Results of Analyzing Air Filter Samples

Lab Number	Filter Number	APED DBF Filename	Installation (from NAB ss)	Volume (m ³)	Weight (g)	Alpha LLD (uCi/ml)	Beta LLD (uCi/ml)	Alpha Act (uCi/ml)	Alpha Unc (uCi/ml)	Beta Act (uCi/ml)	Beta Unc (uCi/ml)
Y2111	5339617		Camp Abdaly	0.0	1.78902	ERR	ERR	ERR	ERR	ERR	ERR
Y2779	5248165		Camp Abdaly	0.0	4.03333	ERR	ERR	ERR	ERR	ERR	ERR
Y4402	5339671	VCTHIVOL.DBF	Camp Thunder Rock	1496.6	0.24202	1.5E-14	2.4E-14	3.7E-15	1.0E-14	2.7E-14	2.0E-14
Y4416	5208810	VCTHIVOL.DBF	Camp Thunder Rock	1977.6	0.32115	1.2E-14	1.8E-14	2.9E-14	1.5E-14	3.4E-14	1.7E-14
Y4777	5339673	VCTHIVOL.DBF	Camp Thunder Rock	1497.5	0.52534	1.7E-14	2.5E-14	4.6E-14	2.7E-14	7.7E-14	2.1E-14
Y5154	5334606	VCTHIVOL.DBF	Camp Thunder Rock	1514.7	0.72600	1.9E-14	2.9E-14	5.1E-14	2.9E-14	5.0E-14	2.4E-14
Y5181	5334625	VCTHIVOL.DBF	Camp Thunder Rock	1506.6	0.58250	1.9E-14	2.9E-14	4.1E-14	2.5E-14	4.5E-14	2.0E-14
Y6461	5209295	VCTHIVOL.DBF	Camp Thunder Rock	2082.6	0.57810	1.3E-14	1.9E-14	3.4E-14	1.9E-14	7.0E-14	1.6E-14
Y6461-dup	5209295	VCTHIVOL.DBF	Camp Thunder Rock	2082.6	0.57810	1.3E-14	1.9E-14	3.4E-14	2.0E-14	7.0E-14	1.6E-14
Y6465	5334650	VCTHIVOL.DBF	Camp Thunder Rock	2081.0	0.43709	1.2E-14	1.8E-14	1.0E-14	1.0E-14	2.0E-14	1.2E-14
Y6467	5209299	VCTHIVOL.DBF	Camp Thunder Rock	1541.2	0.76525	1.9E-14	2.4E-14	1.4E-14	1.8E-14	4.9E-14	2.0E-14
Z0074	5208926	VCTHIVOL.DBF	UN Building	1368.0	0.27416	1.7E-14	2.6E-14	1.6E-14	1.7E-14	5.1E-14	2.4E-14
Z0074-dup	5208926	VCTHIVOL.DBF	UN Building	1368.0	0.27416	1.7E-14	2.6E-14	2.5E-14	2.0E-14	3.9E-14	2.9E-14
Z0747	533264	VCTHIVOL.DBF	U. N. Building	2249.9	0.07966	9.2E-15	1.6E-14	6.8E-15	8.9E-15	1.9E-14	1.0E-14
Z0780	5332676	VCTHIVOL.DBF	U. N. Building	2185.8	1.93675	2.3E-14	1.8E-14	4.4E-14	3.1E-14	3.9E-14	1.7E-14
Z2530	5208678	VCTHIVOL.DBF	UN Building	193.7	0.33430	1.2E-14	1.9E-14	4.7E-14	2.2E-14	4.1E-14	1.8E-14
z2739	5208686	VCTHIVOL.DBF	UN Building	1307.2	0.12905	1.6E-14	2.7E-14	3.7E-14	2.0E-14	3.9E-14	2.3E-14
z2739-dup	5208686	VCTHIVOL.DBF	UN Building	1307.2	0.12905	1.6E-14	2.7E-14	2.7E-14	2.0E-14	3.9E-14	2.3E-14
z3055	5208690			9201.6	1.46960	4.4E-15	4.2E-15	7.7E-15	5.7E-15	9.1E-15	3.9E-15
z3258	KA-5			1160.6	0.07932	1.8E-14	3.0E-14	1.7E-14	1.8E-14	2.1E-14	2.2E-14
z3390	KA-10			1206.7	0.17985	1.9E-14	3.0E-14	2.4E-14	2.1E-14	2.1E-14	2.2E-14
Z4164	KA-22	VCTHIVOL.DBF	UN Building	173.9	0.34718	1.4E-14	2.1E-14	1.6E-14	1.5E-14	4.3E-14	1.4E-14
Z4168	KA-30	VCTHIVOL.DBF	UN Building	1861.4	0.13493	1.1E-14	1.9E-14	4.0E-14	2.0E-14	3.5E-14	1.8E-14
Z4332	K-77	VCTHIVOL.DBF	UN Building	1738.4	0.16700	1.2E-14	2.0E-14	4.3E-14	2.1E-14	3.0E-14	1.9E-14
Z4354	K-81	VCTHIVOL.DBF	UN Building	1846.9	0.12362	1.1E-14	1.9E-14	4.0E-14	2.0E-14	4.0E-14	1.8E-14
Z5479	K-125	VCTHIVOL.DBF	UN Building	1761.7	0.09152	1.2E-14	2.0E-14	5.5E-14	2.0E-14	5.1E-14	2.1E-14
z5560	K-129			1844.0	0.14810	1.2E-14	1.9E-14	3.6E-14	1.9E-14	5.1E-14	2.0E-14
z5970	KA-40			1938.2	0.10115	1.1E-14	1.8E-14	7.8E-14	2.5E-14	3.5E-14	2.0E-14
z5946	KA-46			1859.0	0.10110	1.1E-14	1.7E-14	5.2E-14	2.2E-14	3.5E-14	2.0E-14

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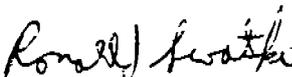
HSHB-ML-RR

SUBJECT: Results of Gross Alpha and Gross Beta Analyses of
Kuwait Air Filters, Project No. 27-22-E24K

12. All results listed in the enclosure have been reported to two significant figures. This has been done to facilitate report generation and eliminate manual transcriptions of the data.

13. Point of contact for additional information is
Mr. Ronald J. Swatski or Ms. Prances Szrom, extension 5-398

Encl


RONALD J. SWATSKI
Chief, Radiochemistry
Analysis Branch



.



HSHB-ML-RR (385-11g)

15 DEC 1993

MEMORANDUM FOR Chief, Health Physics Division (1LT Friedman)

SUBJECT: Results of Gross Alpha and Gross Beta Analyses of Kuwait Air Filters, Project No. 27-22-E24K

1. The additional gross alpha and gross beta analyses of 26 air filters from Kuwait are complete. The results of these analyses are listed in the enclosure.
2. The methodology employed in the air filter analyses was an adaptation of our Gross Alpha and Gross Beta in Soil procedure. An aliquot of each air filter was counted for alpha and beta particles. Average alpha and beta filter background count rates were subtracted from the gross alpha and beta particle count rates. Then, alpha and beta counting efficiencies were assigned and alpha and beta activities calculated based on the volume of air that was drawn through the filter.
3. Average alpha and average beta filter background count rates were subtracted from each sample's gross alpha and gross beta count rates respectively. The average count rates for the filter backgrounds were determined by averaging several alpha and beta count rates of aliquots from unused filters. These filter background aliquots were the same size, shape and area as the actual filter aliquots counted for each sample.
4. Alpha and beta counting efficiencies were based on the weight of particulate matter deposited on the filter aliquot. Basing the efficiencies on the particulate matter weight compensates for self-absorption in the particulate matter.
5. The particulate matter weight on the filter aliquot was calculated by multiplying the weight of particulate matter on the entire filter (from validated APED dBase files) by the percent of the filter counted. The percent of filter counted was determined by dividing the area of the filter aliquot by the filter's total active area (area over which particulate matter was deposited).
6. Since several destructive analyses, such as metals analyses, had been performed on portions of each filter prior to us

HSHB-ML-RR

SUBJECT: Results of Gross Alpha and Gross Beta Analyses of
Kuwait Air Filters, Project No. 27-22-E24K

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receiving the filters, we could not directly measure the size of the entire filter's active area. The entire filter's active area was estimated based on measurements of unused filters. Based on these measurements, we estimated that the filters active areas were approximately 22.9 cm by 18 cm. If this estimation is inappropriate for any filter then the results listed in the enclosure for that filter are incorrect and must not be used. If necessary, results will be re-calculated after we are furnished with actual entire filter active areas.

7. Listed in the enclosure are filter information and results. Filter information was combined from *validated* APED dBase files, an **MAB** spreadsheet file, and **RAB** instrument files. The information was used to calculate the results listed in-the enclosure.

8. Duplicate analyses were performed on approximately 10% of the filters. Two aliquots were analyzed from the same filter as described above. Results of duplicate filters are indicated in the enclosure by appending the suffix "**dup**" to the laboratory number. The duplicate analysis is listed immediately following the original analysis. For example, laboratory numbers Y6461 and Y6461-**dup** refer to the original analysis and the duplicate analysis of Y6461, respectively.

9. Several filters were counted for which data did not exist in the APED files. Therefore, a filename does not appear in the "APED DBF Filename" column of the enclosure. The volumes and weights, if listed for these filters, were calculated from information recorded on the filter envelopes.

10. Information to calculate the air volume of filters Y2111 and Y2779 was not listed on the envelopes. Therefore, results could not be calculated and are indicated in the various result columns by "**ERR**".

11. Results listed include the alpha lower limit of detection (**Alpha LLD**), beta lower limit of detection (**Beta LLD**), alpha activity (**Alpha Act**), alpha counting uncertainty at the 95% confidence interval (**Alpha Unc**), beta activity (**Beta Act**), and beta counting uncertainty at the 95% confidence level (**Beta Unc**). All result units are microcurie per milliliter of air (**uCi/ml**).

HSHB-MR-HI

SUBJECT: Evaluation of Original Kuwait HRA Samples for Depleted Uranium (DU)

7. Points of contact within the Health Physics Division are Mr. David Alberth or 1LT Robert Friedman, x-3502.

Harris Edge
HARRIS EDGE
Chief, Industrial Health Physics
Branch
Health Physics Branch

CF:
DRES
DLS
C, HPD
C, MHPB
C, TOX
C, RAB





DEPARTMENT OF THE ARMY
U. S. ARMY ENVIRONMENTAL HYGIENE AGENCY
ABERDEEN PROVING GROUND, MARYLAND 21010-5422



REPLY TO
ATTENTION OF

HSHB-ME

**FINAL REPORT
KUWAIT OIL FIRE HEALTH RISK ASSESSMENT
NO. 39-26-L192-91
5 MAY - 3 DECEMBER 1991**

**APPENDIX I
RESPONSE TO COMMENTS ON
INTERIM KUWAIT OIL FIRE HEALTH RISK ASSESSMENT**

1. PURPOSE. This appendix addresses all comments received concerning the Interim Kuwait Health Risk Assessment report. Appropriate references are cited where necessary. For clarity, each entity which provided comments is identified with the heading as listed on the comments received. The comments have not been grouped or in any way altered. (Please note that graphs provided by reviewers have been reproduced so as not to alter their initial X and Y axes values.) The reader should notice that several review groups have provided similar comments which are repetively answered in their respective section.

2. COMMENTS FROM REVIEWERS AND RESPONSES FROM THE USAEHA.

A. UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Environmental Criteria and Assessment Office (MD-52)
Research Triangle Park, North Carolina 27111

February 24, 1993

Major William Legg
U.S. Environmental Hygiene Agency
Building E-167
Aberdeen Proving Ground, MD 21010-5422

Dear Major Legg:

Enclosed please find a set of EPA review comments on the draft U.S. Army Kuwait Oil Fire Health Risk Assessment (No. 39-261192-91) forwarded last fall for review by pertinent EPA units. My apologies for the long delay in finally getting these comments off to you, but as noted in our past few phone conversations, higher priority immediate EPA demands (e.g.,

Final Rpt, Kuwait Oil Fire HRA No. 39-26-L192-91, 5 May - 3 Dec 91

budget preparation/submittal tasks) have preempted our being able to wrap up review of the subject Kuwait Oil Fire Risk Assessment. The enclosed comments integrate inputs not only from my ECAO/RTP staff and myself but also from several other EPA units, e.g., AREAL (our atmospheric monitoring/modeling lab) and our fellow OHEA Human Health Assessment Group (HHAG) in Washington, DC.

Our comments focus first on some general issues/concerns regarding (1) organization/structure of the draft risk assessment materials and recommendations for reorganizing the structure to make it more understandable; and (2) aspects regarding PM exposures as probably the single most significant potential health risk to evaluate. Other specific comments then follow the general ones and deal with more specific issues, wording corrections, etc.

We hope you find the EPA comments to be helpful in revising/improving the subject Kuwait Oil Fires assessment materials. Please feel free to contact me (Phone: 919-541-4173; FAX: 919-541-5078) for further clarification/assistance on the matter.

Sincerely yours,
Lester D. Grant, Ph.D.
Director, Environmental Criteria and Assessment Office

Enclosure

USAEHA response: Noted.

U.S. EPA REVIEW OF U.S. ARMY INTERIM KUWAIT OIL FIRE HEALTH RISK ASSESSMENT (No. 39-26-L192-91)

I. BACKGROUND

The U.S. Army undertook this health risk assessment (HRA) to characterize the risk, both cancer and non-cancer, to U.S. DOD personnel and Allied troops and civilians exposed to the environment affected by the oil fires during and after Operation Desert Storm. The project consisted of three main areas: (1) an environmental monitoring effort, with a subsequent HRA; (2) an industrial hygiene sampling study; and (3) a biological surveillance initiative. Upon their completion, the three studies will be incorporated into one report. The present review focuses on the monitoring effort and corresponding HRA. Insufficient data and discussion were provided to allow review of the other two efforts. The industrial hygiene survey was to characterize the occupational exposures of DOD personnel who had potentially high risk exposure to oil fire emissions. Results and data interpretation by the

U.S. Army of the biological surveillance initiative will not be available until the final HEW is released. For the monitoring effort, ambient air sampling was conducted from May 5 through September 15, 1991 in both Kuwait and Saudi Arabia. The analyses and conclusions of the present draft report reviewed are based on those data. Samples collected from September 16 through December 2, 1991 will be analyzed and reported in the final HRA. The draft report draws the following main conclusions from the environmental monitoring and HRA effort:

A. Health Risk Assessment

The data presented for the criteria air pollutants are single average values for particulates, nitrogen dioxide, and sulfur dioxide for all of Kuwait and for all of Saudi Arabia. Based on these single average values, the report concludes that the "magnitude of exposures was low compared to recognized occupational health standards. "The total predicted non-cancer risk from non-criteria air toxics pollutants was calculated by summing hazard quotients calculated for individual contaminants of concern. This summation resulted in a Hazard Index (HI). The HI's for all pathways and routes of exposure range in value from one to four. The majority of non-cancer risk comes from the inhalation of metals, in particular chromium, which represents over 99 percent of the risk. This chromium contamination is believed to be from natural and anthropogenic sources, and not from the oil fires.

The total predicted excess cancer risk estimated to result from human exposure to the Persian Gulf environment ranged from 2×10^{-7} to 5×10^{-7} . These cancer risk levels are below the EPA range of concern of 10^{-4} to 10^{-6} . Also, there is little difference in the cancer risk levels estimated for any of the sites monitored.

B. Air Pathway Analysis

Based on the analyses thus far, only the magnitude of human exposure has been determined. The frequency and duration of exposure will be addressed in the final HRA.

Oil fire pollutants may not have made a significant contribution to a degradation of the pre-war air quality. Comparison of these data with historical air quality data indicates that the air quality at ground level at some sampling sites was better in 1991 than in previous years, for some pollutants.

Mean concentration values for organic compounds were found to be comparable to levels in Houston and Philadelphia. Generally, concentrations of polycyclic aromatic hydrocarbons were at or below detection limits. While high levels of particulate matter were measured,

such levels are considered "normal" for this area of the Middle East. Relatively high concentrations of naturally occurring metals associated with wind blown surface soils were observed.

Regional air quality trends were more strongly influenced by site-specific factors such as terrain, geography, atmospheric dispersion, source characteristics, chemical fate, and meteorology, and were not as strongly influenced by the extent of contamination of the sources.

C. Soil Pathway Analysis

The few increases in concentrations of metals that occurred are probably not fire-related, but are of natural or anthropogenic background.

USA/EHA response: Noted.

II. REVIEW COMMENTS

A. General Comments

In general, the draft report, as now written, is a cumbersome assemblage of data, on which lengthy calculations have been executed, but out of which only limited information has been distilled. Additionally, the organization of the report is very erratic, appearing as if the report is a compilation of various sections prepared by different authors and without any comprehensive editing.

It is recommended that consideration be given to reorganize the next version of the report to treat relevant topics in the following ideal sequence, so as to enhance its logical flow and improve understanding of reported information:

USA/EHA response: sequencing of the discussions in this report follow the guidelines set forth in the EPA document "Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A) , EPA/540/1-89/002, December 1989." This methodology was chosen for its acceptance in dealing with human health risk in the scientific and engineering communities. Specific responses are provided for the following sub-discussions.