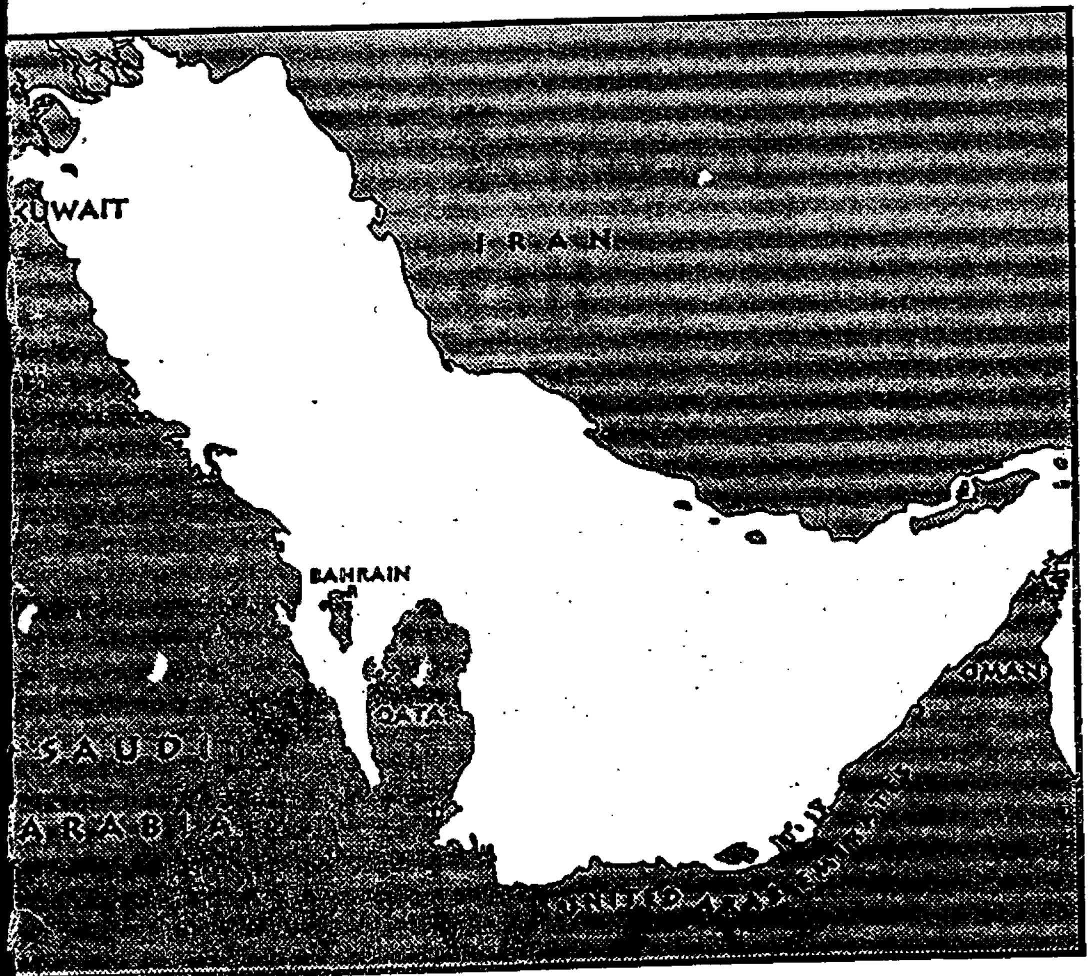
Stop 3201

1.6



Kuwait Oil Fires:

Interagency Interim Report

April 3, 1991

KUWAIT OIL FIRES
INTERAGENCY INTERIM REPORT

I. SUMMARY

More than 500 oil well, storage tank and refinery, and facility fires are currently raging in Kuwait and each day produce an enormous amount of smoke and other pollutants. The quantity and character of the smoke plumes are not yet certain, and the fires are expected to continue for some period. The fires originate in seven oil fields, located both north and south of Kuwait City, with the majority centered in the Al Burgan oil field south of the Kuwait City airport. The fires may represent one of the most extraordinary manmade environmental disasters in recorded history.

In response to this situation, the Saudi Government requested U.S. technical assistance on the public health and environmental impact of the fires. The U.S. Embassy in Saudi Arabia concurred in this request, and voiced its additional concerns about the health effects of the fires on the hundreds of thousands of U.S. troops in the region as well as the thousands of American citizens residing in Saudi Arabia and the other Gulf countries. Similar concerns were also expressed in Kuwait. An Interagency Air Assessment Team consisting of representatives from the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, and the Department of Health and Human Services was formed and deployed to the Persian Gulf area. In country, this team was supplemented by representatives of the United States Coast Guard, the Department of Defense, and the Department of Energy. Re II #11

The specific mission of the team was to assess the conditions through air sampling and monitoring in oil fields and other areas to determine the effect on public health; to review the health infrastructure; to determine the capability of the region to deal with the health threat through air monitoring and appropriate corrective action; to provide technical assistance; and to consider appropriate follow-up action.

Meteorological conditions over the past two months have tended to transport the smoke plume toward the southeast, with periodic excursions toward the northeast. March through July are relatively windy months; there are normally 30 days of very strong winds from the northwest in this period, which produce sandstorms and rapidly ventilate the smoke. From August to October, the incidence of strong winds should drop sharply. The plume is generally below about 12,000 feet. As the summer progresses, it is possible that the height of the plume will increase and that it will then be evident to greater distances.

Emissions from oil fires may have the potential of causing health effects of both an acute and chronic nature, although there is considerable uncertainty as to the extent of the threat. Chemicals such as sulfur dioxide and hydrogen sulfide as well as carbon monoxide and polycyclic aromatic hydrocarbons are often found along with particulate matter in oil fires. While only a limited assessment is possible at this time, the Team did not detect such chemicals in any significant quantity; also, preliminary analysis of the substantial amount of particulate matter did not reveal any chemicals at levels of concern. Additional testing is needed to better define if other toxic materials may be associated with the high levels of particulates found.

The host nation governments also provided the Team with an abundance of preexisting air monitoring information covering the past several years in Saudi Arabia, Kuwait, and Bahrain. These data provide

a useful baseline on limited parameters for comparing the conditions that exist and may evolve during the next several months. The Team concurred with the Saudi Government's view that the considerable Saudi public and private sector competence in air monitoring would need to be supplemented with support and technical assistance. This situation is even more acute in Kuwait City due to the lack of power and to the disruption of the governmental and scientific infrastructure. The Team considered it of critical importance that additional technical assistance be made available to the countries, if requested.

There is need to consider the overall problem from several perspectives so as to ensure economy as well as success. First, because high levels of particulates were found in the air, and prolonged exposure to particulate matter may contribute to respiratory discomfort and perhaps long-term or permanent respiratory disorder, it will be necessary to find out what is in the plume and how it varies over time and distance. Second, we should assess the immediate and long-term human health risk. Third, we should quantify effects on the environment, especially on crops and climate.

II. TEAM'S ACTIVITIES AND FINDINGS

With the assistance of the Saudi and Kuwaiti Governments, the U.S. Interagency Air Assessment Team has been conducting a reconnaissance survey of the fire plumes and their effects in Kuwait and Saudi Arabia since March 10, 1991. The primary objective of the Team was to obtain preliminary, short-term data on the emissions from the smoke emanating from the oil well fires at a variety of locations, in order to:

1. Determine if there is an acute health threat associated with the Hydrogen Sulfide (H_2S) and Sulfur Dioxide (SO_2) and particulates, three pollutants that might be emitted from burning oil wells;

2. Identify and quantify the gaseous and particulate byproducts being produced from the burning oil wells; and

3. Determine if the materials associated with these fires are affecting areas where American citizens are located.

4. Assess the potential extent of the health effects related to the emissions from the fires and the status of the Kuwaiti and Saudi health infrastructure.

Based on these objectives, limited, real-time data was obtained directly from the Kuwait oil fields, as well as from Kuwait and Saudi Arabia locations where embassy officials, troops, and citizens work and reside. Additionally, the Team conducted a number of interviews with health officials to evaluate the extent of acute respiratory problems related to smoke exposure. While only a cursory assessment is possible at this point, some data obtained by the team were encouraging. The preliminary findings are as follows:

1. Limited sampling did not reveal the existence of high concentrations of sulfur dioxide or hydrogen sulfide near the burning wells or in population areas in the path of the oil well emissions;

2. High levels of particulate were found in the air;

3. The results of the current monitoring findings and health interviews with medical personnel in the affected areas suggest that at the present time susceptible subpopulations, such as individuals with asthma and chronic obstructive lung disease, may experience exacerbation of their symptoms. Special health concerns, warnings, advisories, and precautions are clearly warranted for these individuals. This situation does not appear to be life threatening under current exposure conditions but, if meteorological conditions change, i.e., poor air mixing or plume touchdown, there could be adverse health effects for these susceptible individuals; and,

4. The long-term effects on health are not readily ascertainable at this time due to insufficient data on the populations exposed, the composition of the smoke plume, the impact of oil pools, and long-term meteorological patterns. Both the Kuwaiti and Saudi health communities have expressed great interest in obtaining training and support from the US medical community that can be continued by themselves in future years. Aggravating the problem is the severe damage done to the scientific infrastructure of Kuwait thus limiting the current in-country analytic capabilities. Any response by the US would have to include both training and equipment.

The Team has stressed, however, that their observations represent only a preliminary assessment and that considerable follow-up will be necessary to evaluate definitively the nature and magnitude of the human health, ecological, and atmospheric effects of the oil fires. Such follow-up activities will need to be carefully coordinated with the governments in the region as well as with other governments and international organizations, such as WMO, WHO, and UNEP, which are seeking to assist in evaluating the situation.

III. PROPOSED PROGRAM

The local populations are being exposed to an increased health risk, the magnitude of which cannot be estimated with any degree of certainty without further measurements and surveys. The extent to which conditions may worsen needs to be understood and a forecast capability developed. Without such measurements and assessment, and development of a predictive capability, the regional population remains exposed to an uncertain risk, and reconstruction of the area may be impeded. Moreover, without such input, an accurate and defensible quantification of environmental effects will not be possible.

In addition to providing direct answers to questions regarding the effects of the smoke plumes on the atmospheric environment, intensive studies of the plumes will accelerate progress in understanding manmade effects on regional and global air quality, meteorology, and climate. Because the expected changes in air chemistry, solar radiation, and cloud microstructure are so large, observations of these processes could circumvent the need for many years of study directed at much lesser phenomena.

The program proposed below is comprised of three primary elements: human health surveillance and risk assessment, air monitoring, and development of a forecast capability. These elements will be closely linked to achieve the goals of understanding and predicting the degree of human health risk and the effects on atmospheric processes.

1. *Air Monitoring*

The objective of the air monitoring program is to collect the necessary data to determine the nature and concentration of pollutants associated with the fires, and demonstrate the recovery of the environment as the fires are extinguished.

The development and deployment of an integrated monitoring network will serve several interrelated purposes. It will assure data consistency throughout the region. It will provide better data to assess the immediate health risk and potential for long term risks. It will be used to initiate, test, and refine forecast models discussed later in this plan, and thus greatly assist in the development of location and condition specific alerts -- assisting in issuing special advisories for populations at risk under unique conditions. Lastly, it will provide a better basis for scientific understanding and knowledge of the important regional and international issues and will assist in assessing possible extended consequences of the fires.

The U.S. Interagency Air Assessment Team is working with the Saudi Arabian Meteorology and Environmental Protection Agency (MEPA), Saudi ARAMCO, and King Fahd University of Petroleum and Minerals to develop an air monitoring plan for the Gulf Region that will provide the air monitoring data to assess the impact of the Kuwaiti fires in Saudi Arabia. While focused primarily on the needs of Saudi Arabia, the plan forms the general basis for a regional network that should meet the needs of other Gulf nations as well.

The following activities are proposed in cooperation with and support of the host governments:

- Immediate steps would be taken to collect and analyze meteorological observations and forecasts, record visual observations of the smoke plume, and review existing monitoring data. Plume observations via satellite would be obtained daily, supplemented by periodic on-scene aerial transects designed to characterize the overall geometry of the plume.

- A ground-based sampling network of portable equipment would be installed by EPA and others at approximately 15-20 locations to measure particulate matter less than 10 microns in diameter (the particle size most likely to penetrate deeply into the lungs). The ratio of the less than 10 micron particles to total particulate load would be established. Limited organic analysis would be undertaken.

- Measurements of carbon monoxide, carbon dioxide, methane, hydrogen sulfide, sulfur dioxide, particle size distribution, elemental and organic carbon, metals, polycyclic aromatic hydrocarbons, and acid aerosols would be obtained close to the fires by NASA and NIST. These measurements should attempt to characterize and categorize emissions from several specific wells.

- Specially equipped aircraft from the University of Washington (April 15 to May 15), NCAR (May 1 to June 1), and NOAA (July 1 to August 1) would be deployed to measure downwind plume composition and dispersion, radiative properties and climatic effects, and effects on clouds and precipitation. On the basis of the initial aircraft results, a longer-term sampling program would be designed to monitor the relaxation of the atmospheric environment as the fires are extinguished.

EXHIBT 1: Air Sampling Results

U.S. EMBASSY, KUWAIT

Results for 3/16

PAHs:
none detected — detection limit: 2 - 4.6 ppb

Sulfur Dioxide:
none detected — detection limit: 0.04 mg/m3

Inorganic Acids:
HNO_3 5ppb — detection limit: 1 - 6 ppb

VOCs:
Benzene 0.4 ppb, n-Heptane 0.13 ppb, Toluene 0.61 ppb, Ethylbenzene 0.1 ppb, para-Xylene 0.29 ppb, o-Xylene 0.12 ppb.

Metals:
Na < 1.0 ug/m3, Mg 2 ug/m3, Fe 2 ug/m3, Ca 8 ug/m3, Al 2 ug/m3.

Results for 3/17

PAHs:
Naphthalene 0.31 ppb

Sulfur Dioxide:
< 0.02 mg/m3

Inorganic Acids:
HCl 3.0 ppb, H2SO4 1.0 ppb, HNO3 2.0 ppb

VOCs:
Cyclohexane 1.31 ppb, Benzene 4.0 ppb, n-Heptane 6.0 ppb, TCE 0.7 ppb, Methylcyclohexane 2.0 ppb, Toluene 7.7 ppb, n-Octane 3.0 ppb, Ethylbenzene 1.7 ppb, p-Xylene 5.4 ppb, Styrene 0.4 ppb, o-Xylene 2.4 ppb, n-Nonane 1.9 ppb, Cumene 0.2 ppb, Mesitylene 0.6 ppb, D-Limonene 0.1 ppb, n-Decane 1.5 ppb, n-Undecane 1.0 ppb, n-C12 0.7 ppb, n-C13 0.4 ppb.

Metals:
Na 10 ug/m3, Mg 2 ug/m3, Fe 3 ug/m3, Ca 10 ug/m3, Al 2 ug/m3.

EXHIBT 1: Air Sampling Results

U.S. EMBASSY, KUWAIT, continued

Results for 3/18

PAHs:

Naphthalene 0.16 ppb

Sulfur Dioxide:

< 0.05 mg/m3

Inorganic Acids:

HCl 6 ppb, HNO3 2 ppb, H2SO4 1.0 ppb.

VOCs:

Cyclohexane 1.2 ppb, Benzene 5.2 ppb, n-C7 8.1 ppb, Methylcyclohexane 3.0 ppb, Toluene 14.6 ppb, n-C8 4.7 ppb, Ethylbenzene 3.2 ppb, p-Xylene 9.3 ppb, o-Xylene 4.7 ppb, n-C9 2.7 ppb, Cumene 0.3 ppb, Mesitylene 1.3 ppb, Naphthalene 0.18 ppb, n-C10 1.7 ppb, n-C11 1.0 ppb, n-C12 0.7 ppb, n-C13 0.3 ppb.

Metals:

Na 5 ug/m3, Mg 1 ug/m3, Fe 1 ug/m3, Ca 7 ug/m3, Al 1 ug/m3.

EXHIBT 1: Air Sampling Results

CAMP FREEDOM

Results For 3/17

PAHs:

Naphthalene 0.09 ppb, 2-Methylnaphthalene 0.06 ppb, 1-Methylnaphthalene 0.04 ppb.

Sulfur Dioxide:

0.12 mg/m3 0.045 ppm

Inorganic Acids:

HCl 16 ppb, HF 23 ppb, H2SO4 31 ppb

VOCs:

Cyclohexane 7 ppb, Benzene 4.6 ppb, n-C7 25.6 ppb, Methylcyclohexane 9.5 ppb, Toluene 13 ppb, n-C8 18 ppb, Ethylbenzene 2.7 ppb, p-Xylene .8 ppb, o-Xylene 4.5 ppb, n-C9 10.9 ppb, Cumene 0.5 ppb, Mesitylene 1 ppb, Naphthalene 0.18 ppb, n-C10 6.3 ppb, n-C11 4.1 ppb, n-C12 2.3 ppb, n-C13 0.9 ppb, n-C14 0.5 ppb. These levels may also include emissions from vehicles in the area.

Metals:

No Data.

Results for 3/18

PAHs:

Naphthalene 0.28 ppb

Sulfur Dioxide:

<0.04 mg/m3 , < 0.015 ppm

Inorganic Acids:

HNO3 4.0 ppb, H2SO4 4 ppb.

VOCs:

Cyclohexane 2.8 ppb, Benzene 6.9 ppb, n-C7 9.7 ppb, Methylcyclohexane 3.9 ppb, Toluene 16 ppb, n-C8 5.4 ppb, Ethylbenzene 3.1 ppb, p-Xylene 9.5 ppb, Styrene 0.3 ppb, o-Xylene 4.5 ppb, n-C9 3 ppb, Cumene 0.3 ppb, Mesitylene 1.1 ppb, n-C10 1.5 ppb, n-C11 0.8 ppb, n-C14 0.2 ppb.

Metals:

Al 2 ug/m3, Ca 8 ug/m3, Fe 2 ug/m3, Mg 2 ug/m3, Na 3 ug/m3.

EXHIBT 1: Air Sampling Results

MEPA DHAHRAN, SAUDI ARABIA

Results For 3/13

PAHs:
none detected

Sulfur Dioxide:
<0.1 mg/m3, <0.037 ppm

Inorganic Acids:
H2SO4 5 ppb.

VOCs:
Benzene 0.3 ppb, Cyclohexane 0.1 ppb, Toluene 0.5 ppb, Ethylbenzene 0.1 ppb, p-Xylene 0.2 ppb, o-Xylene 0.1 ppb, Mesitylene 0.04 ppb.

Metals:
Al 2 ug/m3, Ca 5 ug/m3, Fe 2 ug/m3, Mg 2 ug/m3, Na 1 ug/m3.
Cd o.o1 ug/m3

Results For 3/14

PAHs:
none detected

Sulfur Dioxide:
<0.08 mg/m3 , < 30 ppb.

Inorganic Acids:
HNO3 2 ppb, H2SO4 6 ppb.

VOCs:
Cyclohexane 0.2 ppb, Benzene 0.5 ppb, n-C7 0.8 ppb, Methylcyclohexane 0.3 ppb, Toluene 0.7 ppb, n-C8 0.4 ppb, Ethylbenzene 0.1 ppb, p-Xylene 0.3 ppb, o-Xylene 0.1 ppb, n-C9 0.3 ppb.

Metals:
Al 3 ug/m3, Ca 14 ug/m3, Fe 3 ug/m3, Mg 4 ug/m3, Na 8 ug/m3.

EXHIBT 1: Air Sampling Results

U.S. EMBASSY RIYADH, SAUDI ARABIA

Results For 3/28

PAHs:
none detected

Sulfur Dioxide:
< 0.08 mg/m3 , < 30 ppb

Inorganic Acids:
NO3 3 ppb, H2SO4 < 2 ppb.

VOCs:
Benzene 0.3 ppb, Toluene 0.6 ppb, Ethylbenzene 1.0 ppb, p-Xylene 0.3 ppb.

Metals:
Al 8 ug/m3, Ca 4 ug/m3, Fe 1 ug/m3.

PORT SHUAYBAH

Results For 3/17

PAHs:
no data

Sulfur Dioxide:
< 0.05 mg/m3, , 19 ppb

Inorganic Acids:
H2SO4 19 ppb.

VOCs:
Benzene 4.2 ppb, n-C7 13 ppb, Methylcyclohexane 5.3 ppb, Toluene 15 ppb, n-C8 5.6 ppb, p-Xylene 6.9 ppb, Ethylbenzene 2.2 ppb, o-Xylene 2.9 ppb, n-C9 3.8 ppb, Cumene 0.2 ppb, n-C10 2.9 ppb, n-C11 1.9 ppb, n-C12 1.4 ppb, n-C13 0.8 ppb.

Metals:
Ca 4 ug/m3, Na 7 ug/m3, AL 2 ug/m3.

EXHIBT 1: Air Sampling Results

Al MAQUA OIL FIELD

Results for 3/15

PAHs:
no data

Sulfur Dioxide:
<0.3 mg/m3 , <0.1 ppm

Inorganic Acids:
no data

VOCs:
Cyclohexane 0.6 ppb, Benzene 1.8 ppb, n-C7 3.2 ppb, Methylcyclohexane 1.1 ppb, Toluene 2 ppb, Ethylbenzene 0.4 ppb, p-Xylene 1.4 ppb, o-Xylene 0.8 ppb, n-C9 2.8 ppb, Mestilylene 0.3 ppb, n-C10 3.3 ppb, n-C11 3.5 ppb, n-C12 3.3 ppb, n-C13 1.8 ppb, n-C16 1.1 ppb.

Metals:
Al 8 ug/m3, Ca 6 ug/m3, Fe 6 ug/m3.

EXHIBT 1: Air Sampling Results

Al AHMADI OIL FIELD

Results For 3/16

PAHs:

none detected

Sulfur Dioxide:

0.45 mg/m3 , 0.17 ppm

Inorganic Acids:

H_2SO_4 27 ppb, HNO_3 10 ppb, HCl 9 ppb.

VOCs:

Cyclohexane 0.4 ppb, Benzene 3.9 ppb, n-C7 2.5 ppb, Methylcyclohexane 3 ppb, Toluene 2 ppb, n-C8 2.3 ppb, Ethylbenzene 0.5 ppb, p-Xylene 1.5 ppb, o-Xylene 0.9 ppb, n-C9 2.9 ppb, Mesitylene 0.4 ppb, Naphthalene 0.5 ppb, n-C10 3.4 ppb, n-C11 3.8 ppb, n-C12 4 ppb, n-C13 2.9 ppb, n-C14 2.9 ppb, n-C15 2 ppb, n-C16 1.7 ppb.

Metals:

Al 7 ug/m3, Ca 4 ug/m3, Fe 20 ug/m3.

Formaldehyde:

8 ppb.

Hydrogen Sulfide: ND 0.3 ppm - detection limited .

SUMMA Data:

SO_2 0.2 ppm; CO 1.9 ppm

EXHIBT 1: Air Sampling Results

AI BURGAN OIL FIELD

Results For 3/17

PAHs:

none detected; detection limit 50 ppb

Sulfur Dioxide:

1.8 mg/m3 , 0.67 ppm

Inorganic Acids:

H_2SO_4 30 ppb, HNO_3 32 ppb, HCl 15 ppb.

VOCs:

Benzene 8.7 ppb, n-C7 4.6 ppb, Methylcyclohexane 2.5 ppb, Toluene 4.31 ppb, n-C8 5.1 ppb, Ethylbenzene 1.3 ppb, p-Xylene 4.2 ppb, o-Xylene 2.4 ppb, n-C9 7.1 ppb, Naphthalene 1.6 ppb, n-C10 9.1 ppb, n-C11 10.4 ppb, n-C12 11.3 ppb, n-C13 7.8 ppb, n-C14 7.4 ppb, n-C15 5.4 ppb, n-C16 4.6 ppb.

Metals:

Al 20 ug/m3, Ca 120 ug/m3, Fe 20 ug/m3, Mg 30 ug/m3.

Formaldehyde:

20 ppb;

SUMMA Data:

SO_2 0.23 ppm, CO 1.6 ppm, H_2S none detected (0.1 ppm detection limit.)

EXHIBT 1: Air Sampling Results

Al WAFRA OIL FIELD

Results for 3/19

PAHs:
no data

Sulfur Dioxide:
none detected 0.3 mg/m3 , 0.11 ppm.

Inorganic Acids:
none detected 10 ppb detection limit

VOCs:
Benzene 2.3 ppb, n-C7 0.6 ppb, Methylcyclohexane 1.6 ppb, Ethylbenzene 0.3 ppb, o-Xylene 0.4 ppb, Mesitylene 0.4 ppb

Metals:
no data

Hydrogen Sulfide:
ND 0.16 ppm dection limited.

SABIRIYAH OIL FIELD

Results For 3/17

SUMMA DATA:

Ground Level Sample:
H2S none detected (0.1 ppm); SO2 0.13 ppm; CO 1.1 ppm; NO and NO2 none detected

VOCs:
Benzene 9.8 ppb, Toluene 8.7 ppb, Ethylbenzene 10 ppb, m&p-Xylene 27.8 ppb o-Xylene 24 ppb, m-Ethyltoluene 15.8 ppb, n-C6 83 ppb, n-C7 60 ppb, n-C8 91 ppb, n-C9 91 ppb, n-C10 89 ppb, n-C11 65 ppb.

3000 ft Sample:
H2S none detected; SO2 0.08 ppm, CO none detected; NO and NO2 none detected 0.5 ppm.

1000 ft Sample:
H2S, SO2, CO, NO, and NO2 none detected.

Table 1
Kuwait Oil Well Fires Real Time Monitoring
March 13-20, 1991

Site, Date, Time	Total Particulate mg/m³	Sulfur Dioxide ppm	Hydrogen Sulfide ppm	Volatile Organics ppm
1) MEPA Faciltiy, Dhahran, SA 3/13 1100 hrs	.170	0.0	0.0	0.0
MEPA Facility 3/14 1300 hrs	.480	0.0	0.0	0.0
2) Al Dhuba 3/15 1430 hrs	.420	0.0	0.0	0.0
3) Umn Al Haiman 3/15 1500 hrs	.320	0.0	0.0	0.0
4) Mina Abdulla 3/15 1530 hrs	.250	0.0	0.01	0.6
5) Near Al Maqwa Oil Field 3/15 1630 hrs	.010	0.0	0.024	0.8
6) In Al Maqwa Well Plume 3/15 1700 hrs	5.4	0.0	0.006	0.8
7) U.S. Embassy 3/06 0900 hrs	.01	0.0	0.001	0.0
U.S. Embassy 3/18 1230 hrs	.055	1.0	0.005	0.2
8) In Al Ahmadi Well Plume 3/16 1230 hrs	—	0.0	0.032	0.0
In Al Ahmadi Oil Field 3/16 1300 hrs	.120	1.0	0.009	0.0
9) In Al Burgan Well Plume 3/17 1100 hrs	—	1.0	0.015	0.0
10) In Sabiriyan Well Plume, Pooled Oil 3/18 1530 hrs	—	1.0	0.042	2.5
11) In Al Wafra Well Plume 3/19 1200 hrs	.050	2.0	0.015	0.0
12) Freedom City	—	—	—	—
13) U.S. Embassy Riyadh, SA 3/20 1300 hrs	.032	0.0	0.0	0.0

Table 2
Kuwait Oil Well Fires Real Time Monitoring
March 24-27, 1991

Site, Date, Time	Total Particulate mg/m^3	Sulfur Dioxide ppm	Hydrogen Sulfide ppm	Volatile Organics ppm
1) Al Safer Motorway and Wafra Road 3/24 1440 hrs	.825 (15 min. avg.)	2.0	0.0	0.3
2) Al Ahmadi Gathering Center #22 3/24 1530 hrs	.359 (15 min. avg.)	0.0	0.0	0.0
3) Al Ahmadi Hospital 3/24 1530 hrs	.222 (32 min. avg.)	0.0	0.0	0.0
4) 1 mi. NW of Station 2 in Ahmadi Oil Field 3/24 1730 hrs	.256 (10 min. avg.)	0.0	0.0	0.0
5) Al Maga Oil Field, .5 mi south of 7th Ring Road near oil pool 3/25 1400 hrs	.034 (17 min. avg.)	1.0	0.0	0.6
6) Al Ahmadi Oil field (same as Station 4) 3/25 1500 hrs	.561 (13 min. avg.)	0.0	0.003	0.6
7) Al Ahmadi Hospital (same as Station 3) 3/25 1545 hrs	.295 (15 min. avg.	0.0	0.0	0.0
8) Al Safer and Wafra Road 3/25 1615 hrs	.065 (16 min. avg.)	0.0	0.002	0.0
9) Al Ahmadi Hospital (same as Station 3 and 7) 3/27 1020 hrs	.935 (20 min. avg.)	0.0	0.0	0.2
10) Al Ahmadi Hospital (same as Stations 3, 7, and 9) 3/27 1040 hrs	.457 (20 min. avg.)	—	—	—
11) Al Ahmadi Hospital (same as Stations 3, 7, 9, and 10) 3/27 1100 hrs	.457 (20 min. avg.)	—	—	—
12) Shuaiba Port 3/27 1215 hrs	.468 (15 min. avg.)	0.0	0.0	0.0

Site, Date, Time	Total Particulate mg/m³	Sulfur Dioxide ppm	Hydrogen Sulfide ppm	Volatile Organics ppm
13) Al Safer Motorway and Wafra Road 3/27 1300 hrs	.119 (12 min. avg.)	0.0	0.0	0.0
14) 16 Kilo-meters SE of Al Safer and Wafra Roads 3/27 1330 hrs	.257 (12 min. avg.)	0.0	0.0	0.0
15) 27 Kilo-meters SE of Al Safer and Wafra Roads 3/27 1350 hrs	.227 (15 min. avg.)	—	—	—
16) 5 Kilometers South of Khafji, Saudi Arabia 3/27 1510 hrs	.072 (14 min. avg.)	—	—	—

Table 3
Sulfur Dioxide Bubbler Measurements
(Acidimetric Method)
Temporary Hospital Locations in Kuwait City
March 13-24

Hospital	Date	Concentration (ug/m³)
Adan	3/14/91	40.31
	3/17/91	43.88
	3/18/91	39.34
	3/19/91	26.18
	3/20/91	27.68
	3/23/91	28.16
	3/24/91	15.99
Mubarek Al Kabeer	3/13/91	193.66
	3/18/91	56.48
	3/19/91	58.11
	3/20/91	42.34
	3/23/91	43.43
	3/24/91	23.72
Al Farwaniya	3/13/91	81.32
	3/16/91	19.21
	3/17/91	29.56
	3/18/91	134.81
	3/19/91	218.65
	3/20/91	27.57
	3/23/91	26.66
	3/24/91	10.54
Al Jahra	3/16/91	32.03
	3/18/91	66.59
	3/19/91	32.54
	3/23/91	13.92
	3/24/91	9.90

APPENDIX B

A REGIONAL GULF AIR MONITORING PLAN IN RESPONSE TO THE 1991 KUWAITI OIL FIELD FIRES

I. INTRODUCTION
- Purpose of the Plan
- Team Membership
- Concerns and Questions - Short and Longer Term
- Basic Understandings

II. BACKGROUND
- Nature of the Fires and Oil Field Locations
- Qualitative Meteorological Observations
- Preliminary Air Quality Information
- Health Issues and Concerns
- Data Bases and Information Management

III. RECOMMENDATIONS
- Preliminary Findings and Conclusions to Date
- Phased Steps for Expanding the Network
- Measurement Parameters at each Site
- Health Monitoring Surveys

IV. SUMMARY
- Preliminary Findings and Conclusions to Date
- Basic Network Requirements
- Urgency and Timing
- Phased Approach to Implementation
- Unresolved Issues

ATTACHMENTS

- List of existing and proposed air monitoring sites
- Locations of existing and proposed air monitoring sites

APPENDIX B

A REGIONAL GULF AIR MONITORING PLAN IN RESPONSE TO THE 1991 KUWAITI OIL FIELD FIRES

1. INTRODUCTION

The U.S. Interagency Air Monitoring Team is working with the Saudi Arabian Meteorology and Environmental Protection Agency (MEPA) to develop an air monitoring plan for the Gulf region that will provide information to assess the impact of the [Kuwaiti] fires in Saudi Arabia. This plan is being discussed and developed with the King Fahd University of Petroleum and Minerals in Dhahran, the Cooperation Council for the Arab States of the Gulf (CCG), and the Saudi Arabian Oil Company (ARAMCO). The plan is being developed at the request of Dr. Tawfiq, Vice President of the Saudi Arabian MEPA. Meetings have been held with officials from all of the above mentioned organizations.

II #11

1.1 Approach

The Team is gathering information on the existing air monitoring networks in the region operated by MEPA, ARAMCO, Kuwait, Bahrain, and the Royal Commission of Jubayl and Yunbo. The spatial distribution of the existing network in the Region is being reviewed as to the location of sites, the air pollutants and meteorological variables that are monitored at each of these sites and the quality of existing data. That review is to determine if the existing network needs to be expanded in terms of the air pollutants and meteorological variables monitored and additional air monitoring stations to determine the impact from the oil fires. The capabilities of the existing agencies and governments to deal with a more complete network is also being investigated.

1.2 Objectives of Air Monitoring in the Gulf Region

Air monitoring data is needed for the following reasons:

a. To provide an Early Warning Health Advisory System for the Gulf Region to respond to the air pollution resulting from the Kuwaiti oil fires. The proposed Early Warning System could be based on an adaptation of the U.S. Air Quality Index, the Pollutant Standards Index (PSI), which can be modified to use Saudi air quality standards. The index would provide for health advisories to the affected populations so they can minimize their exposure to high pollution levels.

b. To track the air pollution from the Kuwaiti oil field fires over time to asses the potential long term health and ecological effects. The air monitoring network proposal being developed is being coordinated with a parallel effort to develop a health monitoring information system.

c. To collect samples of airborne particles to perform toxicity testing and dose response assessment utilizing in-vivo animal models.

d. To facilitate evaluations of models which are use to predict the local and regional scale behavior of the oil field emissions. Data from the expanded GULF REGIONAL AIR MONITORING NETWORK of ambient air quality and meteorological data will be important for those evaluations.

2. BACKGROUND

2.1 Preliminary Investigation of the Existing Monitoring Networks

The air quality monitoring sites listed in Table 1 have been identified for each of the Gulf nations that could contribute monitoring information within the sphere of influence of airborne effluents from the Kuwait oil fires.

Based upon our review of the existing networks, the principal pollutants which are missing are in the Saudi network and in the present Kuwaiti network are PM_{10}, which represents particulate matter with particles less than 10 microns in diameter, polycyclic aromatic hydrocarbons (PAH) and volatile organic compounds (VOC). With respect to PM_{10}, these are the particles which are most likely to penetrate deeply into the lung. It should be noted that Kuwait has collected particulate data using an Anderson Cascade Impactor, with limited size distributions below seven microns within a total suspended particulate sample. Because of the importance of this particular pollutant and the extensive particulate resulting from the oil fires, the Team is recommending that special efforts be initiated to gather PM_{10} data and if possible to determine its constituents - trace metals and hydrocarbons. The
PM_{10} data collection effort should be supplemented with the collections of PAH samples and if possible, grab samples for VOC analysis.

An ongoing effort is being conducted to examine the analytical laboratory support for air monitoring in Kuwait, MEPA, KFUPM, and Saudi ARAMCO. The Kuwaiti laboratory capability to analyze air and particulate samples has been left largely intact. As of March 27, 1991, two of the three continuous monitoring stations have been activated and are collecting data. The remaining site has its continuous sampling equipment however, like the analytical laboratory, is without electrical power. There is no projected date for power at these locations. The analytical laboratory has had experience with polyurethane foam (PUF) extractions for PAH measurements (PS-1 sampler) and has done pesticide extraction and analysis research. The most critical need for the laboratory is obviously power to provide the basis of future support to the sampling plan. Additionally training must be provided with documented procedures for these new sampling and analytical procedures, and lastly they are in need of a complete set of standards to support instrument calibrations for their existing continuous monitors and the new proposed technologies. Quality control and quality assurance samples and support for the network should be developed within the available laboratories but, should be supplemented from an external source.

The analytical laboratory at King Fahd U.P.M. has recently been provided the above procedures to permit a self assessment of their equipment availability to conduct these detailed analyses. Currently, the K.F.U.P.M. is conducting experiments on PAH's analysis of high volume filters as a first step in this program. K.F.U.P.M. has not had any experience with PUF, VOC canister analysis, or PM_{10} sampling and analysis. They have on hand the capability to expand their current analytical capability to provide support to the proposed network.

The analytical laboratory of Saudi ARAMCO as with MEPA has had no experience in collecting and analyzing particulate PM_{10} samples, PUF, and canister samples for VOC speciation and PAHs.

In summary, the current level of technical competence within all of the facilities visited, MEPA, King Fahd U.P.M., Saudi ARAMCO, and Kuwait, indicates that upon the procurement of adequate equipment, standards, and training, they all could support the sampling and analysis required for this program.

TABLE B-1. The Distribution of Air Pollutant and Meteorological Monitoring Sites by Gulf Nation.

Nation	Organization	Number of Air and Met Sites
SAUDI ARABIA	MEPA	3 fixed sites - meteorology and air pollution at different locations of the same city
		1 mobile site - meteorology and air pollution
		1 fixed meteorology site
	Saudi ARAMCO	8 air quality sites with meteorology
		6 additional meteorology sites
	Royal Comm. for Jubayl & Yunbo	Cluster of Five Stations in Jubayl
KUWAIT		3 sites with continuous monitors (2 with power, 1 without power).
		4 sites with Anderson samplers, high vols. and dustfall buckets. (no power)
		1 additional TSP site (no power)
		6 additional dustfal' sites
		4 temporary S02 bubbler sites located at 4 hospitals (some power)
BAHRAIN		2 sites
QATAR		3 mobile monitoring sites
IRAN		unknown
IRAQ		unknown

A substantial number of meteorological measurement sites exist within the eastern provence of Saudi Arabia and the nations of the Gulf Region. Most of those sites are along the shoreline of the Gulf. ARAMCO operates 14 sites with meteorological data. Eight of those sites have collocated air quality measurements. Three of those sites are over the Gulf waters on platforms or on an island. MEPA (Saudi Arabia) has five sites with collocated air quality measurements. In addition, there are surface observations collected at many of the airports throughout the kingdom. Surface meteorological data are being collected at other Gulf region locations. Their locations may be identified through the WMO publications. Previously, there were other surface measurement sites within Kuwait but their operational status remain unknown at this time.

Two upper air balloon sounding sites are operating within Saudi Arabia. One site is at Dhahran and the other is about 115 miles to the SW of Kuwait City at Al Qaysumah. Twice daily soundings are collected at those locations, at 0000 and 1200 GMT. Prior to the war in Kuwait, twice daily upper air soundings were made at the Kuwait International Airport. the resumption of those soundings could be of substantial benefit to describing the airflow across the areas of Kuwaiti oil fires.

2.2 Meteorological Observations

The following summarizations are based upon first hand observations of the smoke plumes and fires. Those observations were made during overflights and during vehicle traverses both within the oil fields and along roads outside of the burning oil fields.

For any given day, the prevailing large-scale meteorological pattern will be the main driving feature which determines where the smoke plumes will be located and how dense they will be.

Individual smoke plumes appear to act in manners typical of buoyant plumes from ground level sources or plumes from short chimneys. Plume rise, the development of a bent-over plume geometry, etc., seem to apply to the individual well-head fires; some have jets of fire and others are nearly surface based burnings of the more combustible fractions of crude oil spread across the ground in the vicinity of the well. Most of the fire plumes rise to between 500 to 1000 feet above ground level before becoming mostly bent over, although some plumes have a significant amount of smoke remaining within a few hundred feet of the ground.

Collectively, as groups of multiple fires within oil fields with a high density of burning wells (particularly Greater Burgan), they assert a meteorological influence of their own. It is suggested that the grouping of fires with a horizontal diameter of 15 to 25 miles provides enough of an intense "heat-island" that significant additional vertical rise of the smoke occurs inside the area. That additional plume rise lifts smoke to elevations often 3000, 4000, to 5000 feet above ground within the initial few miles downwind. Eventually, portions of the smoke rise even more, with multiple layers often forming at heights up to 8000, 9000, even 12000 to 13000 feet. Between such layers and at the tops of layers many tens of miles downwind, a generally diffuse and homogenous zone of smoke has been observed. The eventual smoke height limits are bounded by the regional vertical temperature structure and synoptic weather characteristics. Information reviewed to date suggest that those maximum heights are mostly 8000 to 12000 feet within the initial 100 to 200 miles downwind from the Kuwaiti oil field fires.

With the creation of a local heat-island, a distinct inflow of near surface air has been observed within the initial 500 to 1000 feet above ground level. At times, that inflow of wind is estimated to be 5 to 15 m/sec in strength. Smoke plumes at the peripheral bounds of the burn area tend to slant inward toward the center of the burning field instead of pointing downwind with direction of the expected ambient wind.

Local variations in daily wind flow, along with the fire-storm like winds, are likely to produce preferred locations and times of day at which more concentrated smoke plume exposures reach ground level. Prevailing winds are from the northwest throughout the year. During the daytime a sea breeze can be expected to develop at the Gulf shoreline and progress inland as the day progresses. That inflow of air can readily clear out the smoke plumes and yield substantially cleaner air at ground level on the Gulf side. Along the leading edge of the sea breeze front there likely may be a zone of extended and elevated exposures to fire effluent. That zone may well extend down the shoreline from Kuwait City some 100 km. The area of greatest susceptibility appears to be to the southeast of fires in the Al Ahmadi oil field (part of the greater Burgan field).

2.3 Data Base Management

In addition to evaluating the existing air monitoring networks, the Team made an initial review of existing data systems to handle the air monitoring data. The previous meteorological, air quality, and visual observations of the oil field fire plumes should be archived, along with data to be obtained during the period of on-going Kuwaiti fires. A dedicated facility for the performance of that archiving does not appear to exist. The data management task is likely to be a sizeable task and extended of a period of a year and more.

Some of the general functional needs of the data management system include the following. The data which will need to be assembled into the data base will likely come from many different sources and exist in diverse formats and media. One role of the data base management activity will be to assemble all information into a common, uniform structure. The second and equally important part of the data archiving is the provisions of a uniform and consistent mechanism for the retrieval of data by participating agencies. The degree to which that data base is well formulated, will significantly affect the efforts of users of the data as they attempt to study and interpret the measurements.

A number of possible methods exist for the set-up of a computerized data base. Commercial software and hardware of various degrees and complexity and cost exist which would satisfy the data management needs. Before the choices of system software and hardware are made, the functionality of the overall system and the manners in which users work with the data sets should be considered. For example, it may be required that the data base be a "relational" data base. Other sources of software that might be used to handle a large volume of data would be the U.S. Environmental Agency's (USEPA) Aerometric Information and Retrieval System. That system can handle hourly data and has considerable software available to both summarize and analyze the ambient air data.

MEPA has asked the Team to recommend the type of computer and associated software needed to manage the data collected in order to implement the monitoring plan. For now, it is more appropriate to defer specific recommendations. A number of general performance characteristics may be stated but specific details should be formulated in conjunction with data base specialists at a later date.

RECOMMENDATIONS

While preliminary, the Team believes that the following recommendations should be implemented based on our initial data gathering exercise. A general objective is listed as a recommended goal and below that objective are listed several needed items or activities to facilitate the achievement of the overall goal.

1. Objective: Provide a framework for an early warning advisory capability for areas expected to be impacted by effluents from Kuwaiti oil field fires.

   Needs:
   - a. Meteorological data observations and forecasts
   - b. Visual observations from key receptor areas
   - c. Review existing monitoring data
   - d. Calculate smoke trajectories and concentrations

2. Objective: Provide a cursory wide-area indication of the distribution and composition of the Kuwaiti oil field fire effluents.

   Needs:
   - a. Establish 10 to 15 PM_{10} monitoring locations using portable monitors.
   - b. Train personnel in the operation of the portable PM-10 monitors and develop the analytical support capability within Saudi Arabia and Kuwait.
   - c. Define the PM_{10} to TSP ratios.
   - d. Define the composition of the plume by XRF analysis for limited organic identification.
   - e. Establish a central media preparation and analysis location.
   - f. Define the baseline contribution of the ambient aerosol from the surrounding desert.

3. Objective: Characterize the aerial smoke plume.

   Needs:
   - a. Collect many of the same plume measurements recommended for the ground monitoring array
   - b. Collect descriptions of the width and vertical extent of the smoke plume at several downwind distances
   - c. Characterize the regional background by samples outside of the smoke plumes

4. Objective: Develop a more complete profile of the smoke plume constituents

   Needs:
   - a. Procure equipment for a limited number of comprehensive air quality monitoring stations to collect: TSP, PM_{10}, organic, and inorganic constituents
   - b. Establish a limited number of comprehensive air quality monitoring stations to collect: TSP, PM_{10}, organic, and inorganic constituents. These should be collocated with the continuous monitors wherever possible.
   - c. Train individuals to operate and maintain the sampling instrumentation in support of the monitoring program
   - d. Procure the necessary analytical laboratory equipment required for analyses of the samples collected under this objective
   - e. Train laboratory personnel in the preparation of the sampling media, QA/QC procedures required and the subsequent sample analytical procedures.

5. Objective: Determine the need for expansion of the monitoring network to a wider regional coverage.

Needs:
a. Review the data developed from the limited network.
b. Assess the current and projected status of control of the oil field fires and emissions.
c. Review the population health survey statistics.
d. Review the suitability of the sampling strategy, and modify where needed
e. Expand the limited network as the situation requires, data analysis indicates an additional need for data, the response of the affected populations indicate, or the model requires additional parameters.

Many of the same considerations listed for air quality above also apply to meteorological considerations.

6. Objective: Provide a meteorological data stream to facilitate the modeling and prediction of areas expected to be impacted by effluents from Kuwaiti oil field fires.

Needs:
a. Upper air balloon sounding data representative of the Kuwaiti oil field fire area and Gulf region plume transport.

b. Supplemental surface based measurements of wind speed and direction, temperature, moisture content of the air (dew point, relative humidity, etc.), solar radiation, atmospheric pressure, precipitation.

7. Objective: Provide a meteorological data set to investigate the areas of climate modifications occurring due to effluents from Kuwaiti oil field fires.

Needs:
a. Supplemental surface based measur)ments diffuse and direct solar radiation.

b. Special collections of precipitation throughout the region to examine the pH and chemistry of the rains.

c. Aircraft soundings and profiles of smoke, winds and temperatures, air quality related measurements of plume compositions and concentrations representative of the Kuwaiti oil field fire area and Gulf region transported plumes.

4. PHASED AIR MONITORING PLAN

This section of the report discusses a prioritized plan of stepwise incremental actions for the phased implementation of the recommendations discussed above. Five phases for implementing the plan follow.

4.1 Phase 1. Provide a Framework for an Early Warning Advisory

In order to accomplish this task, the following action items need to be initiated or incorporated into the task framework.

1. Gather daily weather forecasts to predict meteorological conditions which would effect pollution potential in both Saudi Arabia and Kuwait.
2. Use visual observations from key receptor sites to determine possible pollution levels.
3. Gather existing air monitoring data from fixed and mobile sites operated by MEPA, Saudi ARAMCO, and the governments of Kuwait and Bahrain to develop a data base of existing data.
4. Establish a daily briefing for representatives of the many entities concerned with behaviors and fate of the aerial effluents from the oil field fires in Kuwait.
5. Develop a daily map depiction of the aerial distribution of the smoke plumes across the region using satellite imagery, for each day since initiation of the oil field fires.
6. Issue a daily general statement about the expected behavior(s) of the oil fire plumes. Areas of potentially adverse conditions could be treated as locations for which advisories would be issued.
7. Provide forecast meteorological conditions across the region for the next 2 to 3 day period, including the expected location(s) of the smoke.
8. Obtain data from the MEPA network throughout the eastern province.
9. Direct the crews of the SLAR aircraft, (USCG Falcon Jet), to continue on a regular basis the present visual observation and mapped notations concerning the horizontal extent of the smoke plumes and the estimations of altitudes of layer bases and tops.
10. The above information could be compiled initially in hard copy form. Later it should be stored on electronic media in a way that an existing PC data management system could readily incorporate it.

4.2 Phase 2. Establish a PM_{10} Monitoring Network Using Portable PM_{10} Monitors.

Working in conjunction with the Saudi Arabian Meteorology and Environmental Protection Agency (MEPA), the proposed plan has been developed to collect information on PM_{10}, which represents particulate matter with particulates less than 10 microns in diameter. At the present time there is no PM_{10} monitoring in the Gulf region.

OBJECTIVES

The objectives for this effort are as follows:

1) Determine the magnitude or the health threat to residents of population centers and field-based military personnel impacted by the oil field fires and typical sources (windblown desert soils).

2) Establish a scientifically based capability to alert these affected populations prior to the onset of the potential health threats from real-time measurements.

3) Establish a technical basis for executing predictive air quality dispersion models which simulate the oil well fire emissions, background sources, and consequent impacts over space and time.

4) Establish a regional network of PM_{10} stations using a consistent monitoring methodology across the countries of Saudi Arabia, Kuwait, and Bahrain.

5) Train personnel to operate and analyze the media produced by the network from each of the participating countries.

6) Develop a regional data base and encourage the sharing of data developed from the network with all participants.

The above objectives convert the foregoing goals into discrete actions:

1) Determine the spatial temporal frequency, and severity of the impact to the resident populations and military centers affected through the application of saturation sampling techniques with portable PM_{10} samplers.

2) Establish the correlation of real-time surrogate monitoring data to date generated from direct sampling methods through the collocation and simultaneous operation of both methods over time.

3) Where possible use impact data collected from samplers as an input to the dispersion model, run the model "backwards" to develop a better estimate of the emission rates of the fires and produce a higher level of confidence in the predictive modeling results.

4) Obtain from the literature and/or develop from source sampling analysis chemical profiles of all major pollutant sources in order to:

a) identify those contaminants that pose the greatest health concerns and to develop an estimate of acceptable ambient levels (AALs) prior to the conduct of field work,

b) identify the chemical "signature" of the major contaminants and other tracers characteristic of the primary sources,

c) enable apportionment of these contaminants and other tracer compounds from a simple total mass concentration measured by the ambient samp'es, and

d) attempt to relate these levels in turn to the surrogate real-time monitoring methods for use in issuing timely health risk alerts.

5) Ensure that the data generated by the network are of a demonstrably high quality (precision & accuracy), completeness, representativeness, and comparability.

TIME	POSITION (LAT/LONG)	BASE/TOP	WIND (DIR/SPD)
0545	N2623E50-31	CLR VIS 15 M	332/23
0600	N2700E4958	CLR	321/19
0615	N2744E4916	CLR	300/20
0630	N2822E4839	TOPS 070/030	331/008
0645	N2918E4819	SMOKE 060/030	335/10
0700	N2932E4810	SMOKE 070/030	344/10
0715	N29344830	SMOKE 070/030	265/7
0730	N29354857	THIN SMOKE 050/030	215/6
0745	N2925E4920	VERY THIN SMOKE 090	133/003
0800	N2833E4945	THICKER SMOKE 090/ 080	326/006
0815	N2738E5035	THIN SMOKE 090/080	280/005
0830	N2702E5111	SMOKE 090/060	192/010
0845	N2625E5148	SMOKE/HAZE 080/060	215/12
0900	N2618E5118	SMOKE/HAZE 070/SURF	230/009

APPROACH

Conduct a PM_{10} saturation sampling study for the determination of the temporal and spatial features of the impact of the oil well fires and attempt to reconcile the data with existing model estimates. PM_{10} mass concentrations would be available within 24-48 hours following sampling. No on-site meteorological, gas, or aerosol monitoring or chemical analysis is required (chemistry could be attempted later on the preserved media). One or more portable nephelometers would be collocated at several sampling sites to develop correlations between manual and continuous (real-time) methods for alert advisories.

A total of 15-20 portable PM_{10} samplers equipped with quartz filters would be run simultaneously on a daily basis or "triggered" (impact forecast) basis throughout the study area. Network design would involve a "nested" approach to address the objectives:

1) samplers sited at background locations (not impacted) by the smoke plume and samplers in populated areas.
2) samplers in populated areas impacted by smoke.

Samplers could be "ganged" (2 or more) and programmed to run consecutively at individual sites if filter clogging problems occur because of high loading. Further, multiple samplers could be collocated at certain sites to collect fine particulates (less than 2.5 microns) and coarse particulates (2.5-10 microns) on teflon sample filters (facilitating XRF elemental analysis). One of the 10-12 sampling sites would be equipped with duplicate samplers in an effort to develop sampling precision estimates.

This comprehensive program will yield the following:

1) short turnaround PM_{10} concentrations,

2) gross estimates of the fire-specific contributions to total mass could be derived by subtracting background concentrations from the impact site concentrations,

3) applying assumptions on the source profiles to pollutant loading attributable to the well fires, estimates of individual target compound loadings could be computed and a comparison to AALs made,

4) correlations factors can be determined between real-time surrogate methods and manual methods, and

5) impacted sampling media would be available for subsequent intensive chemical analysis in an attempt to reconcile assumed source signatures and extracts can be used to perform any other analytical tests (mutagenicity). Special precautions may be needed to preserve the sample integrity during storage and transfer.

Limitations: no on-site meteorological data to calculate emissions rates, no on-site chemistry (unless developed) to confirm critical assumptions, and no concurrent gas or acid aerosol measurements to evaluate or correlate with the particulate data.

Resources: 1-2 professionals, 1 field technician per site, if it must be operated individually (actual number contingent upon the network logistics and potential "clogging" implications), portable PM_{10} saturation samplers, portable nephelometers, lap-top computer, microbalance, expendables and sundry support gear.

In summary, this approach is PM_{10} mass data-rich, and assumption rich and in contrast to being reconciliation and broad pollutant characterization-poor.

SAMPLING AND ANALYTICAL METHODS

The alternate approaches identified above involve the use of a variety of sampling and analytical methods summarized below:

Portable PM_{10} Saturation Samplers

- segregate and capture of filter, particulates of 10 micron size (respirable particles) and smaller.

- battery-operated, lightweight, rugged, inexpensive, small, and quiet.
- easily deployed and operated.
- programmable timer for unattended on and off.
- rechargeable battery packs.
- continuous operation up to 30 hours on a single charge.
- precise and accurate.
- low detection limit of approximately 5 ug/m3
- sustained operation under high particulate loadings, e.g. 100 ug/m3 or more.
- electronic sample flow regulation.
- electronic sample flow totalizer.
- low flow shutoff/warning.
- can accept a variety of other pollutant sampling media (e.g. PUF, DNPH, charcoal, denuders, etc.) or take whole air samples (Tedlar bags) with little or no modification.

Portable nephelometers
- many of the same attributes of the PM_{10}
- battery operated
- effectively measure particulates of 1 micron diameter or smaller.
- continuous reading, storing five minute averages.
- rechargeable.
- continuous operation from 2-48 hours on a single battery charge.
- internal storage for up to nine days of sampling data.
- data download to a portable lap-top computer through RS232 serial port.
- operationally equivalent to standard nephelometers.

Microbalance
- five to six place balance.
- rugged, transportable while precise and accurate.

Field XRF Unit
- similar MQLS with situ laboratory units.
- rugged.

Support Gear
- calibration and audit gear, tools and diagnostic equipment, etc.

PROPOSED NETWORK DESIGN

The recommendation for siting of the portable PM_{10} samplers is predicated on providing a large area of coverage for developing a better estimate of the areas impacted by the plume, a cross-sampling of population and troop centers, and to a capability to provide a technology transfer to Saudi Arabia, Kuwait, and Bahrain.

SAUDI ARABIA
- collocated site at K.F.U.P.M. (2 sites)
- two sites in Riyadh (1 U.S. Embassy & 1 MEPA location)
- one site Royal Commission at Jubayl
- one site Saudi ARAMCO at Tanajib
- one site MEPA at Khafji

Total of seven (7) sites.

KUWAIT

- three sites (3) located at the two operational continuous monitoring sites within Kuwait City (one site collocated)
- one site at Camp Freedom
- One site U.S. Embassy
- One site Al Hamadi (Kuwait Oil Company Hospital)

Total of six (6) sites.

CENTCOM

- two sites at selected troop locations

Total of two (2) sites.

BAHRAIN

- one site to be determined

Total of one (1) site.

A total of sixteen samplers are committed to field sampling with the remainder as spares or as changes to the sampling plan requires.

Phase 3: Characterize the Aerial Plume.

This phase should follow closely with Phase 2, in order to characterize the 3-dimensional nature of the smoke plumes from the fires in Kuwaiti oil fields. To achieve that goal, many of the same plume measurements collected by the existing and proposed ground level measurement locations should be provided by the aerial sampling platform. Obviously, the longer time integrated samples (e.g., 24 hour total values, averages, etc.) cannot be reproduced by aircraft borne devices. Short-term and across plume integrated measurement descriptions may be obtained to characterize the special extent and details of actual constituents of the elevated portions of the oil fire plumes.

The aerial sampling activities may be separated into measurements which address the three general zones of plume characteristics, from an a meteorological sense. Those zones are the 1) close-in zone, 2)intermediate or transition zone and 3)extended or distant zone. Measurements very near the wellhead are difficult to impossible to obtain due to excessive heat and great levels of turbulence. Measurements at intermediate distances will be difficult and many locations within the clustered groups of burning wells may be unsafe for aerial traverses due to the extremely dense smoke and hidden turbulent plumes. Measurements at the longer distances, a few miles downwind of the burning wells, should be possible. Measurements from a few to several hundred miles downwind of the fire area should be feasible. Within that distance range the approximate concentrations, plume dimensions, and estimated mass flux in the downwind directions may be approximated. The aerial sampling strategies should concentrate on the obtaining of those types of information.

4.4 Phase 4. Develop a Complete Profile of the Smoke Plume Constituents.

Obtain additional equipment to expand existing continuous monitoring high priority sites in Kuwait and Saudi Arabia

The survey conducted by the Team during Phase 1 of this plan indicated that within the region, respirable particulate sampling technology, aerosol and total particulate sampling and analysis for volatile organic compounds (VOC), semi-volatile organic compounds (SVOC), and PAHs were either not available or insufficient to properly characterize the effects of the oil well fires on the population centers and the troop concentrations within the region.

This phase of the plan proposes to bring into the region several new technologies and to train personnel within the region to operate samplers, to condition, and analyze the several new media necessary to support this expanded network. The objective of this process is to develop a stand-along capability within each participating country for aerosol and particulate monitoring which will support the Gulf regional air quality characterization and index plan outlined in Phase V:

During this phase of the plan the Team proposes to expand the continuous air and meteorological monitoring currently being conducted within the region at six sites. These sites are recommended based on the need to jointly develop the sampling and analytical capability within the region to ensure that it becomes self-sufficient and sustainable. The particular technologies outlined below are not currently operated within the region nor are the analytical procedures required to support them currently being utilized. However, the Phase I survey indicates that with sufficient training, additional equipment, and some experience with actual field samples the transfer should be relatively smooth.

Initially, the Team's recommendation of six sites strategically placed along the axis of the area of greatest impact by the oil well fire plume will generate sufficient samples for the required training, while also providing critical data not currently being collected by the existing networks or available through the portable PM_{10} network proposed in Phase II. As this data base develops it can be used to better define the constituents of the plume and thus permit a more accurate assessment of the potential long-term health risk.

The equipment listed below should be collocated with the full compliment of continuous air and meteorological monitors described in Phase V at these six proposed sites. A brief description of the equipment is provided below:

TSP High Volume Sample - used to collect a 24-hour sample of the total suspended particulates, operated nominally at 50 OFM, and typically uses 8x10 inch glass fiber, quartz, or teflon filter media.

PM_{10} High Volume Sampler - used to collect a 24-hour sample of the 10 micron and smaller sized fraction of the total suspended particulate sample collected by the TSP sampler above, sampler is typically operated at 40 CFM, and utilizes an 8x10 inch Quartz or teflon filter media. Note: glass fiber media should not be used if there is concern for a known sulfate artifact formation problem.

PM_{10} Manual Dichotomous Sampler - used to collect a 24-hour sample of the 10 micron particulate size fraction of the TSP, sampler operates at 16.7 liters/minute, and utilizes two (2) 37 mm diameter Teflon filters to collect a fractionated sample with a cut point of 0-2.5 micron (fine fraction) and 2.5 - 10 micron (coarse fraction).

VOC Canister Sampler - used to collect up to a 24- hour integrated whole air sample in six-liter evacuated stainless steel canisters, interior walls are passivated to minimize sample degradation, samples volume can be regulated by either limiting the volume to ambient pressure or pumping in addition sample to an approximate volume of 16 liters, these samples can be used for the determination of total hydrocarbons or analyzed for specific hydrocarbons, multiple analysis are available from a single pressurized canister sample. Note: An extensive canister cleanup process is required prior to the collection of additional air samples.

Polyurethane Foam (PUF) Low Volume Sampler - used to collect 24-hour aerosol samples utilizing small AC or battery operated pumps at flow rates less than five liters per minute on relatively small glass cartridges containing a PUF plug, these samples can be extracted and analyzed for PAHs, or other SVOCs. Note: Both the glass cartridge and PUG plug require an extensive cleanup procedure prior to re-use.

Optional Tenex/Charcoal/XAD-2 tubes - these media can be used with same type of low volume pumps described above to collect additional samples for further definition of the constituents of the plume for SVOCs.

Organic compounds will be present in all three phase distributions (particle bound, SVOC, and VOC) and each phase will have to be sampled and then a determination will have made as to importance of each.

The particle bound is phase can be collected for extractible organic analysis from both quartz, teflon impregnated glass fiber filters, or teflon.

The SVOC phase can be collected on PUF and within the canister. The VOC phase can be collected with canisters and charcoal tubes. Employment of Tenex and S/.D-2 sampling tubes in conjunction with PUF, charcoal tubes, and canisters in an overlapping sampling matrix, can be used to confirm of the presence or absence of compounds which could be missed by a less complex sampling matrix.

Proposed locations for the initial six expanded sites:

The Team recommends that the six locations follow the general axis of plume drift from Kuwait City south into Saudi Arabia. It is further suggested that the operation of these sites be divided amongst the key network managers within the two countries: Kuwait, MEPA, and Saudi ARAMCO. This division of responsibility supports the philosophy to jointly develop both the sampling and analytical capability within all three entities.

Kuwaiti Locations

The Team recommends that two (2) of the sites be located at the existing operational continuous monitoring stations located in Kuwait City. A third site should be established in Al-Ahmadi at the Kuwaiti Oil Company Hospital. This location is situated within 300 - 400 meters of several burning wells and is adjacent to the closest residential area associated with any of the oil fields.

Saudi Arabian Locations

The Team recommends that a site be established at King Fahd University of Petroleum and Miners (K.F.U.P.M.) in Dhahran, one site to be collocated with Saudi ARAMCO site in Tanajib and the last site should be collocated with the MEPA site in Khafji which currently is only collecting meteorology data.

4.5 Phase 5. Develop Regional Air Monitoring Network to Track the Impact of the Kuwaiti Oil Fires on the Gulf Region

This phase of the proposal will be developed in a series of stages. The network is directed at long term fixed site monitoring, which will collect a battery of both air quality and meteorological data that would satisfy the objectives identified in this report. Particular attention will be given to providing an early warning system advising the effected public on what cautionary steps should be taken to minimize the impact of air pollution on health. It is proposed that the early warning system will be modeled after the air quality index used in the United States. The second focus will be directed at tracking the air pollution problem over time to be used in determining both long term health and ecological impacts due to the Kuwait oil fires. The data base will provide information to develop key policy decisions which could minimize the possible health and ecological impacts.

Recommended Measurement Parameters at Each Site

The basic plan is for each site within the regional monitoring network to consist of the same types of measurement devices. Deviations for that general consistency will be addressed on an individual basis. Two general categories of information are proposed for every location. Data measurement are grouped into either meteorological or air quality categories.

a. Meteorological variables

The nominal set of meteorological measurements to be collected at each site are the following:

- Wind speed and direction (at 10 m)
- Temperature
- Moisture content of the air
- Dew point, relative humidity, or wet bulb
- Solar radiation
- Precipitation (saved for chemical analysis, pH, etc.)

b. Air quality variables

The nominal set of air quality measurements to be collected at each site are the following. Two general categories of collection needs exist. The first set of needs relate to the onset of episodic levels of airborne concentrations. In those situation a need may be developing for an early warning advisory for downwind population centers. The second set of needs relate to the need to monitor for longer term, more subtle risks.

Episodic/EARLY WARNING measurements		Longer term monitoring
PM_{10}	(continuous)	Acid aerosols
TSP		VOCs
SO2	(continuous)	Aldehydes
O3	(continuous)	BaP, other PAHs

NOx, NO	(continuous)	Trace elements
CO	(continuous)	Fine particles
H2S	(continuous)	

c. Health Monitoring Survey

Air monitoring data collected through the proposed air monitoring network will provide basis for interpreting the results of health surveys of the populations and ecosystems potentially effected by the effluents from the oil fires in Kuwait. The kinds of health data that could be collected include:

Health questionnaires
Blood samples
Hair samples
In-vivo animal studies
Forced expiratory volumes
Other morbidity parameters

Distribution of Proposed and Existing Air Monitoring Sites

Table 2 shows the location of the existing and proposed air monitoring sites, while Table 3 lists the locations of the proposed air monitoring sites. In order to complete the network in an orderly manner, it is proposed that the network be developed in several stages. The first order of business would be to upgrade the existing monitoring locations so that there exist a full complement of air and meteorological monitoring equipment, as well as add new critical air monitoring stages (Stage 1). The second stage would be to establish those sites that would satisfy the minimum requirements for tracking the plume caused by the oil fire and to provide an early warning system for Saudi Arabia, Kuwait, and Bahrain (Stage 2). The third and final stage would be to complete the final network following a review of the quality and quantity of findings to date (Stage).

5. SUMMARY

The initial measurements made by the Team suggest that there is not an imminent threat from SO2 and H2S to the urban populations, while short term measurements of particulate are frequently high. Historically, this region has high particulate levels due to wind blown dust. The particulate measurements that were collected by the Team reflect total particulate, as opposed to respirable particulates, that is PM_{10}. There has not been a principal focus in the Region on total particulate, $PM10_{10}$, and organics up to now. Therefore, the Team developed the five phased monitoring plan with an emphasis on better understanding particulates and the aerosol organics associated with the oil fires in Kuwait. Particulates and organics could be a source of concern for both health and ecological effects.

The air monitoring proposals presented in this report represent the Team's collective judgement on what needs to be done. Those judgements are based upon an on-site evaluation of the situation in Kuwait, discussions with officials from the Saudi Arabian MEPA, Kuwait, Saudi ARAMCO, and the King Fahd University of Petroleum and Minerals. Needless to say more work is needed regarding data management, statistical design, data analysis and quality assurance. Because of the complexity and immediacy of this problem, an extended time commitment will be needed on the part of all Gulf nation agencies to achieve the objectives outlined in this report.

Cost estimates for the various types of air and meteorological monitors are attached to this plan, along with documentation on the U.S. Environmental Protection Agency's Pollutant Standards Index (PSI).

TABLE 2. Location of existing air and meteorology monitoring stations

NATION	ORGANIZATION	LOCATION	STAGE OF IMPLEMENTATION
Saudi Arabia	MEPA	Damman	1
		Hofuf	2
		Tanagib (Mobile Site)	1
		Riyadh	1
	Saudi Arabia	Udhailiyah	3
		Shedgum	3
		Abqaiq	3
		Dhahran	2
		Tartut	2
		Rahimah	2
		Juaymah	1
		Tanajib	1
		Safaniyah Oil Field (met only)	3
		Marjan Oil Field (met only)	2
		Abusafahs Field (met only)	3
	The Royal Comm. for Jubyayl and Yunbo	Cluster of 5 stations in Jubyayl	1
Kuwait		Mansoria	1
		Rabia	1
		Rega	1
Qatar		3 Mobile Units, unknown locations	2

TABLE 3. Location of proposed air and meteorology monitoring stations

NATION	ORGANIZATION	LOCATION	STAGE OF IMPLEMENTATION
Saudi Arabia	MEPA	Awiyah	3
		Shumlul	2
		Sarrar	2
		Nuayriyah	2
		Lisafah	3
		Hafar al Batin	1
		28 deg 8 min latitude, 47 deg 51 min longitude	2
		28 deg 30 min latitude, 48 deg 1 min longitude	1
		28 deg 55 min latitude, 47 deg 32 min longitude	2
		29 deg 7 min latitude, 46 deg 39 min longitude	2
Kuwait		Mina Saud	1
		U.S. Embassy	1
		Al Ahmadi (Hospital)	1
		International Airport	1
		29 deg 23 min latitude, 46 deg 55 min longitude	2
		29 deg 50 min latitude, 47 deg 15 min longitude	2
		30 deg 4 min latitude, 47 deg 42 min longitude	2
		29 deg 33 min latitude, 47 deg 50 min longitude	2
Bahrain		Mina Manama	2
		Bahrain University	2
Qatar		Doha	3
United Arab Emirates		Abu Dhabi	3
		Dubai	3
Oman		Muscat	3