Community Assessment of Air Toxics in Birmingham AL and Vicinity

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ABSTRACT

The Jefferson County Department of Health (JCDH), in partnership with the University of Alabama in Huntsville (UAH) and Battelle Memorial Institute in Columbus (Battelle), proposes to initiate a new program of monitoring and community assessment of air toxics (AT) in the Birmingham AL area, aimed (a) at contributing to EPA's National AT Monitoring and Assessment programs, and (b) at characterizing the local air toxics (emissions, spatial-temporal distribution, source-receptor relationships) as a first step toward exposure risk assessment and development/implementation of reduction strategies. The new *monitoring program* will include two major components: (a) "core" sampling (24h-average every 12 days) and chemical analyses (based on EPA Methods and QAPP) of most of the 33 ATs on EPA's urban HAP list, at 4 fixed AT sites (two microscale source-oriented, one urban neighborhood-scale, and one rural), which will augment the existing larger network of ozone/PM/met monitoring sites (including three sites with PM2.5 speciation); and (b) portable/roving FTIR and met systems (to be located sequentially at several - up to 8 - "roving" sites, including the 4 AT core sites, for 36-96 day durations) to provide greater spatial-temporal coverage, initially of many of the core AT gas species (to be expanded in the future for aerosols also). The monitoring will cover a 12-month period. An *emissions inventory (EI) effort* will assemble an EI of target ATs from permitted industrial sources, perform on-site verification, and prepare an EI database. A *data management effort* will generate and manage a systematic AT database for Birmingham in conjunction with the database of criteria pollutants, and the AT data will be routinely uploaded to EPA's AQS. A rigorous *data analysis/assessment program* will be carried out to characterize, at fairly fine resolution, the spatial-temporal distribution of the target ATs, as well as source-receptor relationships; special focus will be given to the impacts of specific stationary and mobile sources of particular local concern. The project will extend the previous successful collaboration of JCDH and UAH in EPA's EMPACT program, which created an excellent set of mechanisms for *public outreach* (including a dynamic and current website), and these will be extended to ATs also.

1. INTRODUCTION

The 1990 Clean Air Act Amendments (CAAA) identified 188 ATs as Hazardous Air Pollutants (HAPs) of special concern, requiring monitoring, assessment and regulation. These HAPs have been associated with a wide variety of adverse health effects including cancer and neurological/reproductive/developmental disorders, as well as ecosystem effects. EPA's implementation of the CAAA includes its Air Toxics Program (ATP), of which a major activity is the National Air Toxics Assessment program (NATA), aimed at expanded AT monitoring and assessments. The National Air Toxics Monitoring Network is a key part of this effort (also known as the National AT Trends Stations, NATTS). The primary objective of NATTS is to generate AT monitoring data for identifying trends, characterizing ambient concentrations in representative areas, and evaluating air quality models (AQMs). Of particular concern is the relatively large AT exposure in urban areas. The 2001 Urban AT Monitoring Program (UATMP) was designed to focus on ambient monitoring in and near 27 urban areas (EPA, 2002). A Pilot City Monitoring Project (PCMP) was also conducted in 10 urban areas (four large cities and 6 smaller areas) in 2001-2002 with a focus on characterizing spatial-temporal variability. Members of our team played a key role in analyses and assessments of both the PCMP data (Bortnick et al., 2003) and a comprehensive archive of pre-2001 data (Bortnick et al., 2001), aimed partly at providing guidelines for the design of a future national strategy. The new strategy calls for more in-depth community-based studies across the US based on two main principles: first, the community programs must have an appropriate balance between national prescriptive measurements (e.g., trends) and flexibility to address issues of more local concern; second, there needs to be an integration of AT measurements with those of other pollutants, e.g., the criteria air pollutants. We have put together a proposal for a very responsive project, and a versatile team which has the capability to (a) generate a quality AT database with higher-than-usual spatial-temporal resolution through innovative effort, (b) integrate it into a substantial existing criteria pollutants monitoring program, and (c) perform state-of-the-art data interpretations and assessments, with focus on addressing issues of local concern. The innovative effort will involve deployment of a portable/roving FTIR system with relatively high temporal resolution.

2. SPECIFIC OBJECTIVES (TASKS)

1. Initiate a basic "core" AT monitoring/analysis/QA program at 4 fixed sites, based on EPA-approved methods

2. Implement an experimental "roving" monitoring component based on an automated and portable FTIR system
3. Develop a local AT emissions inventory (EI)
4. Implement a Data-Processing/Data-Management component
5. Implement a Data Analysis/Assessment component to characterize the local ATs
6. Extend the existing Public Outreach program to include ATs
7. Extend the existing in-state partnerships to include ATs
8. Create a plan of program sustainability and future evolution
9. Project management

3. THE WORK PLAN (by Task)

3.1 Task 1: The Basic "Core" AT Monitoring/Analysis/QA Component

This component will aim at sampling and analysis of most of the 33 urban ATs identified by EPA, on a 24h-average basis every 12 days, at 4 fixed "core" sites. Six types of sampling/analyses will be performed as follows: VOCs based on TO-15 method (4 sites); carbonyls based on TO-11A (4 sites); SVOCs (semivolatile organic compounds) based on TO-13A (4 sites); heavy metal compounds based on IO-3-5 (4 sites); hexavalent chromium based on CARB-SOP 39 (4 sites); fluoride (1 site). The present proposal requests partial funding for this task, with the remainder coming from a separate concurrent EPA 105 Grant covering AT monitoring at two sites.

Birmingham is in Jefferson County, and JCDH is charged with local air quality management in the County. Figure 1 shows a GIS map of the study area, including major interstate highways, land use (including the "urban/built-up land"), the major known AT sources, and the 17 existing local air quality (AQ) monitoring sites. The distribution of
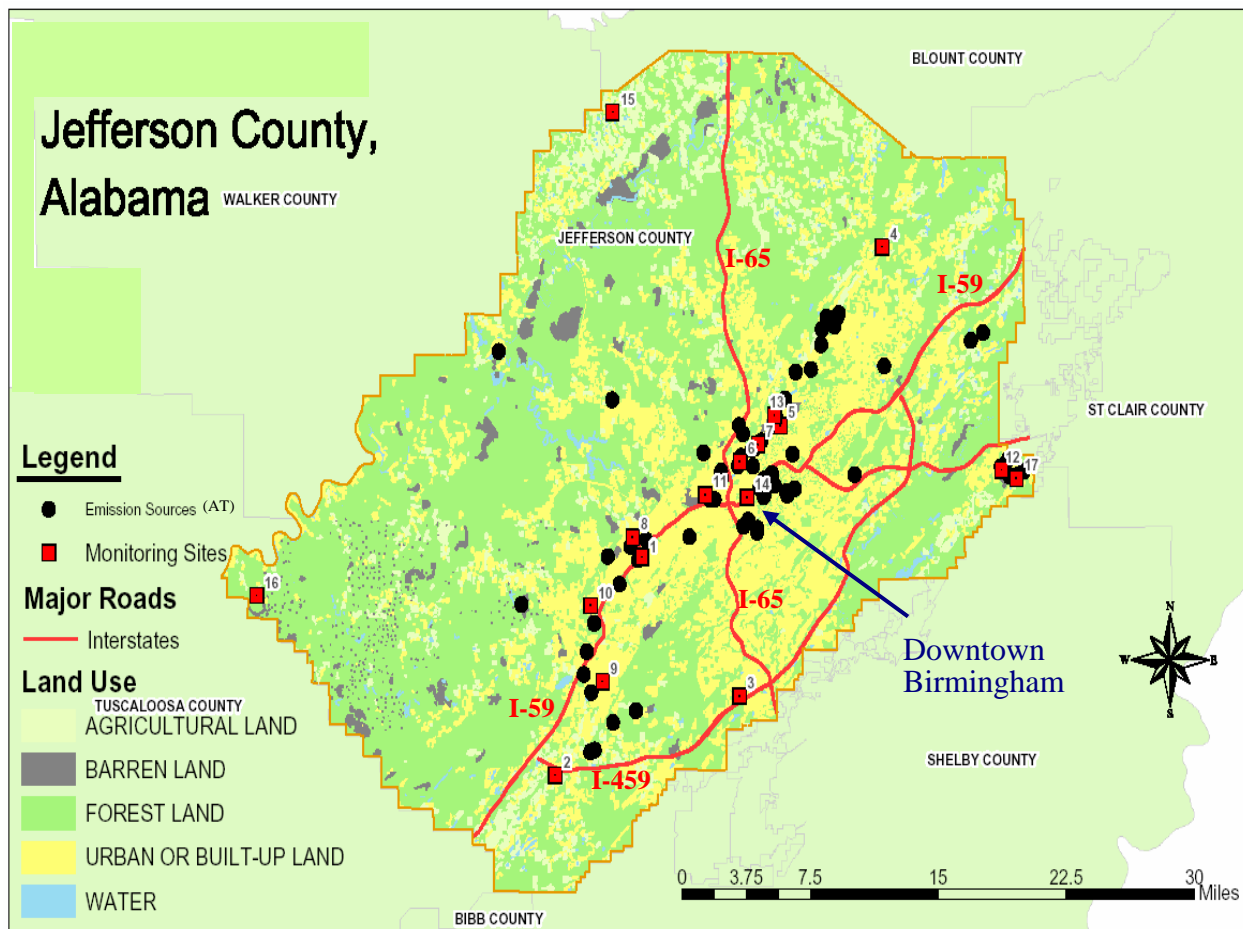
Figure 1. Map of Jefferson CO showing major interstate highways, land use (built-up urban area in yellow), major air toxics emission sources (black circles) and the 17 existing air quality monitoring sites (numbered, red squares). The four "core" AT sites will be at locations 6 (N. Birmingham), 7 (Sloss), 11 (E. Thomas) and 16 (Providence).

pollutants monitored is as follows: ozone (9 sites: 1-6, 12, 15, 16), PM2.5 (continuously at 8 sites: 2, 3, 4, 6, 8, 12, 15, 16; 24h batch-mode/speciation at 6, 8,16), PM10 (at all sites except 11); CO (3 sites: 1, 7, 11), and SO2 (site 1). The following meteorological variables are also measured at the eight continuous PM2.5 sites: temperature, relative humidity, barometric pressure, rainfall amount, insolation, and wind speed/direction.

The heart of the metro area is centered around the intersection of I-59 and I-65, with the business district to the south and major industrial areas to the north. Parts of this industrial area are also environmental justice areas (residential areas for minorities). Site 6 (N. Birmingham) is located a little to the north of the I-65/59 intersection and is a supersite: JCDH monitors ozone and PM10/PM2.5 (continuous and speciated) there; it is also an EPRI-SEARCH site (comprehensive gas, aerosol and met) and an SRI (Southern Research Inst.) aerosol site. It is a representative urban, neighborhood-scale, industrial/residential (environmental justice) site and, as such, an ideal location (we believe) for an urban NATT site. We have chosen this to be one of our four new "core" AT sites. A few kilometers farther to the NE is the Sloss site (#7), immediately next to a large coke plant, and surrounded by minority residences. JCDH has been quite concerned about human exposure to the emissions from the Sloss plant, and we have chosen this site (Sloss) as another of our 4 core AT sites, this one being a stationary-source-oriented site of specific local concern. Our third AT core site will be a mobile-source-oriented site (#11, E.Thomas, at the busy intersection of Finley Blvd. and Arkadelphia Rd., and a little west of the I-65/59 intersection), surrounded simultaneously by heavy traffic and minority residences, and another area of major JCDH concern. Finally, we have chosen Providence (#16) as the location of our fourth AT core site: it is quite rural, far to the SW and typically upwind of Birmingham. We believe that this is an ideal NATT rural site in SE USA. Ozone, PM10, PM2.5 (both continuous and speciated), and the met variables are also routinely monitored at both sites, #6 and 16. Our choice of the 4 core sites is, we believe, a good blend for meeting both the national needs (sites # 6 and 16) and local needs (sites # 7 and 11). All 4 sites will collect separate appropriate samples to be analysed for VOCs (TO-15), carbonyls (TO-13A), SVOCs (TO-11A), metal compounds (IO-3-5) and hexavalent chromium (CARB-SOP 39); the Sloss site will also sample for fluorides. 24-hour PM2.5 samples are also collected (for speciation) at sites #6 (N. Birmingham, every 3 days) and #16 (Providence, every 6 days), and will serve a comparison purpose for our new heavy metals measurements at these sites.

The handling of the sampling canisters/cartridges/filters will be in accordance with EPA-approved methods. The samples will be shipped to Eastern Research Group (ERG) in RTP, NC for analysis within 72 hours of sample run. ERG will perform the analyses in accordance with their EPA-approved Quality Assurance Project Plan (QAPP). After analyses, ERG will enter the data into EPA's Air Quality System (AQS). ERG will clean all tubes and canisters before returning them to us for sampling. For details, see http:/www.ergweb2.com/uatmp/index.htm.

Our QA procedures will be the same as those of ERG-QAPP. Our measurement quality objectives (MQOs) will be as in EPA's QAPP for the AT Pilot Monitoring Program (EPA-454/R-01-007, June 2001), and will be followed especially for benzene, formaldehyde, acrolein, 1,3-butadiene, arsenic and hexavalent chromium. More than 10% of our monitoring program budget will be for QA. We will devote at least 10% of our budget to sample collocations. Monitoring at each site will be for one year on a 12-day cycle. A total of 37 samples (over the year) for VOC (including replicates and duplicates), 48 samples for carbonyls (including replicates, duplicates and field blanks), 48 each for heavy metals and SVOC, and others for chromium and fluorides will be collected and analysed. Data accuracy will be determined by comparison of analyses of duplicate samples and calibration samples exposed to known concentrations. Analytical precision will be estimated by repeated analyses of samples. Duplicate samples will be reanalyzed at least once each to determine overall precision, including sampling and analysis variability. Flow checks will be performed on all samplers at least monthly.

3.2 Task 2: Supplemental Monitoring With the FTIR System

The primary observation of recent AT studies was the need for more in-depth community-scale studies across the country, with focus on capturing local detail (Bortnick et al., 2003). These studies have also recommended finer temporal resolution of the monitoring (Bortnick et al., 2002a; 2002b). While the core monitoring described above will be an important new resource for both the national program and the local response to existing community concerns, it will still fall short of providing the needed spatial-temporal coverage to adequately characterize the local AT situation. Spatially, two core sites (Sloss and E. Thomas) will be focused on assessing the impact of very specific sources of concern; the other two core sites (N. Birmingham and Providence) will be important toward characterizing the community-wide spatial distribution of AT, but will hardly provide adequate coverage. There will be no coverage of the business district, middle-class residential districts, and various other categories of landuse and human exposure. Temporally, the 12-day sampling cycle will provide only spot coverage, which will barely suffice for annual averaging, let alone seasonal characterization (7-8 samples per site only). Also, there will be no characterization of diurnal variability or of transient peaks due to direct "hits" from nearby sources. To fill in some

of these spatial-temporal gaps, we are proposing to deploy an FTIR system, for now limited to gases only (which absorb in the IR bandwidth - mainly the VOCs and carbonyls), but with straight-forward potential for expansion later to include aerosols and SVOCs also. The system we are proposing will be highly automated and portable, and capable of fine spectral and time resolution (as fine as minutes), as well as satisfactory detection limits for many of the sampled species (at 2-3h time resolution). It will perform automated sampling/analysis/data processing, with initial capital cost comparable to the *annual* cost of analyses of the samples from each core site, and will entail relatively small annual on-going operational cost.

Each VOC exhibits an intrinsic multi-line absorption spectrum in the infrared. Line positions serve as "fingerprints" that identify the VOC, while line amplitudes and areas are directly proportional to the amount of the VOC. In principle, FTIR spectrometers can measure these features with high spectral resolution and broad spectral coverage, to provide accurate quantitative analyses in complex mixtures of multiple VOCs and other IR-active gases. Thus, FTIR spectroscopy provides an established monitoring method for industrial emissions, where trace gas concentrations are high. Industrial FTIR systems usually use extractive sampling into closed gas cells with multiple-pass optical paths, or natural ventilation across open spaces with single- or double-pass optical paths. However, these configurations cannot achieve the very low detection limits that EPA requires for VOC trend assessments. The primary difficulties arise from spectral interference (water vapor, carbon dioxide), line broadening (intra-molecular rotations, inter-molecular collisions), spectral resolution (unresolved lines at coarse resolution, excessive noise or integration time at high resolution) and system drift (source, detector, electronics, optics, internal trace gases). Our FTIR system will overcome these important limitations. In what follows, we first outline the manner of deployment of our system and the kind of information it will provide, followed by specific information about the system itself.

Monitoring Plan: The FTIR instrument will provide continuous environmental monitoring (CEM) for VOCs and other IR-active trace gases (e.g., carbonyls) at one selected JCDH station at a time, at two simultaneous time resolutions: 10-15 minutes (to resolve transient peaks) and 2-3 hours (to resolve the diurnal cycle). The system will operate in Birmingham for at least 12 months, being deployed sequentially at up to eight different JCDH sites (including the 4 core AT sites) for periods of 36 to 96 days (to synchronize with the 12-day VOC core sampling cycle, and to provide one full season at N. Birmingham). The resulting data will provide detailed statistical comparisons of collocated FTIR and core measurements, continuous information (between the 12 days, diurnal variation, transient peaks, etc.), and, collectively, broad coverage of the spatial variability of the measured gas concentrations over eight different landuse and human exposure categories.

Deliverables: The FTIR project will have four deliverables: a final report, an integrated instrument system, an instrument manual, and archived data (raw interferograms, processed spectra, derived VOC concentrations, quality assurance statistics, ancillary records). The final report will include analyses of the stand-alone FTIR data (data quality, spatial variability, temporal trends), comparisons of collocated FTIR and core measurements, a standard methodology based on the new FTIR sampler, and preliminary design concepts for system improvements.

System Architecture: Figure 2 shows the primary instrument subsystems. The system is built around a high-performance FTIR, a miniature gas cell with a single-pass optical path, and a high-flow-rate pre-concentrator manifold with four parallel dual-stage traps. These subsystems will integrate with other manifolds for quality assurance, sampling-conditioning, and exhaust-vacuum. Operating conditions will be monitored by temperature, pressure, and flow sensors, and controlled by an autonomous onboard computer. The communications subsystem will provide remote access for data transfer, device health and safety, and contingency command and control.
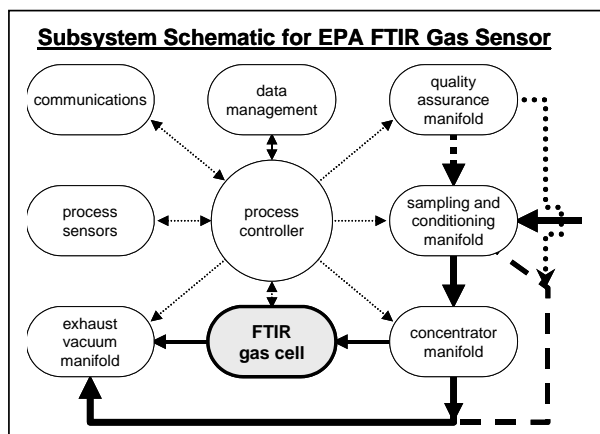

Figure 2. Main subsystems of the proposed FTIR system

Principle of Operation: An exhaust pump will draw filtered, heated ambient air through a high-flow-rate VOC trap. After sampling, the trapped VOCs will thermally desorb into an inert IR-transparent carrier gas (nitrogen), and collect in a low-flow-rate trap. It will then thermally desorb into the evacuated gas cell, reach a standard total pressure (<0.2 atm) with additional carrier gas, and reach the standard temperature (>40°C) of the gas cell walls. The FTIR will measure the transmittance spectra of the concentrated VOCs, using high spectral resolution (0.125, 0.25, or 0.5 cm^{-1}) and a tightly focused beam. Modern chemometric software will compare the measured spectra against an internal spectral library to determine the molar amount of each VOC in the cell. These measurements and the total mass flow through the first trap will yield ambient VOC concentrations.

Distinctive Features: The pre-concentrator, miniature gas cell, and small beam area will maximize the areal density and illuminated volume of the VOC batch sample, and improve the detection limit of the measurement. (Increased cell length is more appropriate for continuous flows, with collimated or weakly focused beams.) The low pressure will narrow the VOC lines, separate overlapping lines, and allow measurements at high spectral resolution, without introducing non-linearity or degrading the signal-to-noise ratio (SNR). These features will improve the sensitivity and temporal resolution of the VOC measurements.

The high-flow trap will separate the VOCs from H_2O, CO_2, and other light gases. This precaution will prevent overloading in the low-flow trap, condensation on the walls and windows of the gas cell, and interfering lines in the transmittance spectra. The chosen separation process will maintain the composition and mixing fraction of each VOC species, whether polar or non-polar. VOC measurements at fixed temperature and pressure will minimize spectral and radiometric errors due to theoretical temperature and pressure corrections. The evacuated cell will provide background spectra between successive VOC samples to correct for instrument drift. The **quality assurance** (QA) manifold will house compressed nitrogen bottles, for carrier, dilution, and purge gas. This manifold will also house NIST-traceable permeation tubes in a temperature-controlled block to provide well-known mixtures of reference, standard, calibration, spike, and tracer gases over a wide range of total and relative concentrations. These features will ensure adequate accuracy, precision, and traceability of the VOC measurements with the FTIR.

The FTIR will use a field-ruggedized optical bench and a high-sensitivity detector with built-in miniature cooler (hence, no need for liquid nitrogen coolant). The manifolds will minimize the use of moving parts. All subsystems will be packaged in a compact, shock-mounted instrument rack, suitable for indoor operation. These features will minimize field maintenance and provide portability, thereby facilitating operation at multiple sites and improving the spatial coverage for VOC assessments.

Sampling Modes: The system will use four sampling modes. In the *rapid mode*, VOC samples will be obtained with high temporal resolution (10-20 min) to capture transient events with high VOC concentrations. To achieve this sampling rate, three trap lines will operate in a coordinated sequence. At any given time, one line will collect and concentrate its VOC sample, the second line will desorb its VOC sample into the gas cell for infrared analysis, and the third line will undergo cleansing in preparation for the next sampling cycle. During these cycles, the fourth trap line will operate in the *threshold mode*. This trap will repeatedly collect VOC samples for 2-3 hr, long enough to achieve the required TDL's, but still short enough to assess diurnal variability. In a daily *quality assurance mode*, all four lines will collect simultaneous spiked samples, using the same sampling duration as in the threshold mode. In this mode, desorption and spectral analysis will occur sequentially from the various trap lines. In all three modes, the control system will randomize trap-line assignments and sequences to minimize sampling biases. In an occasional *calibration mode*, a QA gas mixture will bypass the trap lines and enter the gas cell directly. A vacuum bleed line will allow spectra at multiple pressures for comparison to previous calibrations.

Technology Readiness: Most of the relevant equipment and methods have already been used extensively in other EPA-related measurement programs and have received EPA approval for selected VOC measurements. All other features have been successfully used in other measurement programs. Thus, the proposed FTIR project should actually be considered as innovative packaging of established equipment and innovative combinations of established methods. The resulting instrument system will combine the chemical specificity and high sensitivity of infrared analysis at high spectral resolution and high SNR; the quality assurance of a centralized chemical analysis laboratory; and the programmatic assurance of successful timely implementation and reliable field operation.

The FTIR sample chamber could also accommodate modular cells for aerosols and light trace gases. This configuration would monitor VOC's, gaseous and particulate SVOC's, other IR-active particulate constituents, and other trace gases, using a single, self-contained, internally consistent FTIR analyzer. These instruments would be suitable for mass production, after engineering optimization. The purchase cost for such an instrument would be lower than the annual cost of the current off-site gas and aerosol analyses for a single monitoring station. Recurring annual costs (consumables, maintenance) would be minor. Thus, FTIR technology could provide a cost-effective alternative to EPA's current cartridge, canister, and filter sampling and analyses for aerosols and trace gases.

The Portable Met System: A portable met system measuring wind speed/direction, temperature and humidity will be acquired as part of this project. This will augment the current 7-variable met measurements at N.Birmingham, Providence and the five other sites making continuous PM2.5 measurements. The Sloss and E. Thomas core AT sites do not have met measurements. When the FTIR is at these sites or at any of the other fixed sites without met measurements, the portable met system will also be located there. When the FTIR is at any of the other fixed sites with met measurements, the portable met system will be located at the Sloss core site.

3.3 Task 3: Air Toxics Emissions Inventory (AT-EI) for the Birmingham Area
Limited AT emissions-related data are currently available for most permitted industrial sources. Such data are generated using the following methods: stack tests; AP-42 emissions factors; manufacturer's vendor data; and material safety data. In addition, annual production (activity) data are obtained from submittals to JCDH each February. Such data are used by JCDH engineers and environmental health specialists to calculate/estimate AT emissions, which are entered into an EI database. Data gaps are generally due to non-submittals and absence of AT-specific emission factors from EPA and other sources. Limited AT data are currently available for most permitted industrial sources, but JCDH has little or no information currently about AT emissions from mobile sources and unpermitted area sources (e.g., gasoline stations, dry cleaning facilities, commercial boilers, etc.). JCDH also has some information about the following ATs not included in the core list of urban ATs: COS, HF, MEK, xylene, toluene and coke oven emissions.

In the current project, special efforts will be made to enhance submittals of data from permitted sources and verifications of the quality of the submitted data through on-site inspections, and the most appropriate applicable emission estimation procedures will be employed. A systematic AT-EI database will be created. Data gaps will be identified and guidance will be sought from EPA and elsewhere for ways to narrow these gaps as much as possible.

3.4 Task 4: Data Processing and Data Management (DP/DM)
The current DP/DM procedures applied for the criteria air pollutants monitored routinely by JCDH will be extended to ATs, and a comprehensive combined database will be generated and maintained at UAH. At each of the current monitoring sites, the data from the various continuous analyzers are fed into an intelligent data logger, which processes them to generate hourly average concentrations, which are transferred to the JCDH central computer (CCPU) via a modem line when polled by the CCPU every hour. The data are then transferred to both EPA's database and to our EMPACT website at UAH. The PM2.5 speciated data are not part of the website database now. In the new expanded program, the speciated PM and AT data will also be updated and archived at the central database at UAH. During the project period, a duplicate AT and met database will also be maintained at Battelle.

The FTIR data will also be transferred to UAH from the field site via the CCPU. A switching device will be built to switch the modem connection to either the core site data logger or the FTIR computer. This device will be controlled by tailored software resident on the CCPU, which will switch it periodically to poll data from either of the two sources. Once on the CCPU, the data will be transferred to UAH. UAH will also access the FTIR computer once or twice a day to check out the system performance and to control it as necessary.

The new JCDH air quality database (AQDB) will be maintained on a new computer system of this project. This system will be in communication with the EMPACT system at UAH, which will maintain the expanded website.

JCDH will ensure that appropriate validated data from both the core sampling program and the FTIR program, as determined jointly by JCDH and EPA, will be delivered to EPA's AQS database within 90 days of the end of each quarter of the monitoring program.

3.5 Task 5: Data Analysis/Assessment
A variety of **data analysis tools** will be employed, including an analytical language (SAS), a geographic information system (GIS - ESRI's ArcView), and custom space-time software based on open GL developed at both UAH and Battelle. The primary programming languages will be SAS and IDL (Interactive Data Language). The SAS system will be used to translate and prepare the data for statistical or mathematical analyses. The data are seamlessly retrieved electronically as needed using SAS tools for dynamic data exchange (DDE) or Open DataBase Connectivity (ODBC) functionality. Once the data are accessible to SAS, we will perform SAS data step programming to format and structure the data for the planned data analyses and carry out such analyses. Due to the spatial nature of air monitoring network data, the relevance and usefulness of geographic data can increase manyfold simply by viewing data on a map rather than on a table or graph. Relationships between spatial data that are abstract in tabular, graphical, or mathematical form become apparent when viewed on a map. Thus, GIS can help in both the quality assurance and analysis of data. We regularly use ESRI's ArcView GIS products to develop geographically related presentations. We are familiar with ArcView file formats (shape and dbf/dBase) and with methods of importing external meta-data from other sources into ArcView. Lastly, to visualize the space-time nature of the air toxics data, computer animation software can be applied in order to construct an animated version of the space-time behavior of concentration levels. By interpolating the data over space and time, the software depicts a spatial 3-dimensional surface of the concentration levels that evolves over time. Basically, this procedure provides a temporal movie of the spatial concentration gradients that enables an intuitive visualization of the space-time data.

Our data analyses and assessments will be tailored to satisfy the selection criteria for this solicitation. The top priority will be on **characterization of the spatial-temporal concentration patterns of the key HAPs within Jefferson CO**. The spatial patterns will be discerned from measurements at up to 8 sites - the four core sites and four other sites, selected to distinguish between urban, suburban and rural settings, as well as background, fixed- and mobile-source oriented, and exposure-based. Two of the core sites are ideal candidates for national trend sites, N. Birmingham representing the urban-industrial neighborhood scale, and Providence representing the regional background scale. AT sampling at the four non-core sites will be by the FTIR, one at a time, providing broadened spatial coverage. The temporal resolution will also be broad, ranging from 10-15 minutes (FTIR) to 24-h average (batch-mode, every 12 days).

As standard practice, we will generate appropriate tabular, statistical and graphical data summaries to obtain a better understanding of the local AT behavior before conducting in-depth analyses. Summaries can be generated at the following levels: overall pollutant, pollutant by site, pollutant by location setting (urban, suburban, rural), and pollutant by land use type (e.g., background, mobile-source oriented, exposure-based, etc.). More specifically, our data analysis summaries will include the following: scatter plots of AT concentrations (pollutant-to-pollutant, pollutant-to-met variable, etc.); time series plots involving multiple sites and/or multiple pollutants, as well as annual, seasonal, and/or monthly average AT concentrations plotted over time; GIS plots that overlay multiple layers of information such as monitoring sites, sources, population density, core urban areas, land use, AT concentration information, etc. (e.g., Fig. 1, which does not include concentrations information); summary statistics tables and side-by-side box plots indicating sample size and related statistics, information of non-detect results, comparisons by pollutant, site, by location setting, or by land use type; etc.
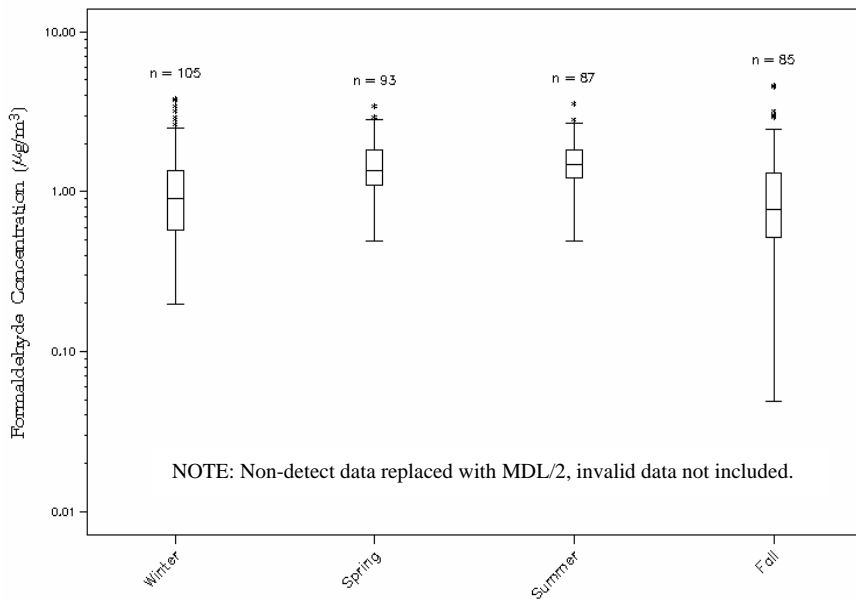

Figure 3 provides an example box plot summary of formaldehyde data collected at several monitoring sites, by season. The horizontal axis displays the season; the vertical axis represents formaldehyde concentration in $\mu g/m^3$. The number displayed on top of each box plot indicates the relevant sample size. Box plots also graphically display a useful five-statistics summary: the bottom of the box is at the 25th percentile of the data, the middle at the 50th percentile (median), and the top is located at the 75th percentile. The bottom and top whiskers are located at a maximum of 1.5xIQR below and above the median, respectively (IQR = interquartile range, the separation between the 25th and

Figure 3. Box plot of daily formaldehyde at several monitoring sites, by season

75th percentiles). Data beyond this range are called "outliers" and are represented in the plot with an asterisk. This plot reveals some level of seasonality in formaldehyde, with the higher concentrations in the warmer seasons, most probably due to the increased photochemical production caused by intensified light and heat in the summer months.

Figure 4 displays a time series plot of daily arsenic TSP at an air toxics monitoring site. Arsenic TSP concentrations at this site reached high levels during eight out of nine consecutive sampling days between September 16 and November 9, 2001. These levels were higher than any other concentrations throughout the rest of the year at this site. To get a sense of where these large concentrations were coming from, a pollution rose was created using the SAS System and is shown in Figure 5. According to the pollution rose, the higher concentrations occurred when the wind was blowing from the NE direction, during low and high wind speeds. This result suggested that there was a source nearby in the NE direction from the site. Further investigation of the area surrounding the monitoring site revealed a rock-crushing gravel pit approximately three miles NE of the site. Further information gathered indicated the rock and dirt in the area may be high in arsenic and manganese; thus, there is a possibility that the rock crushing pit to the east could be emitting arsenic.
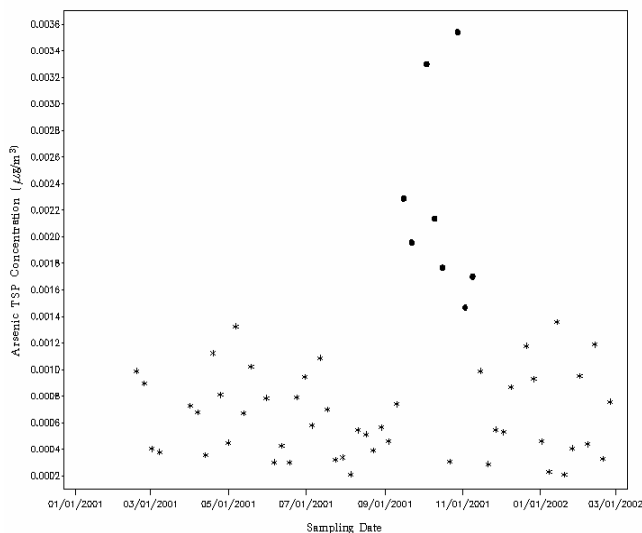
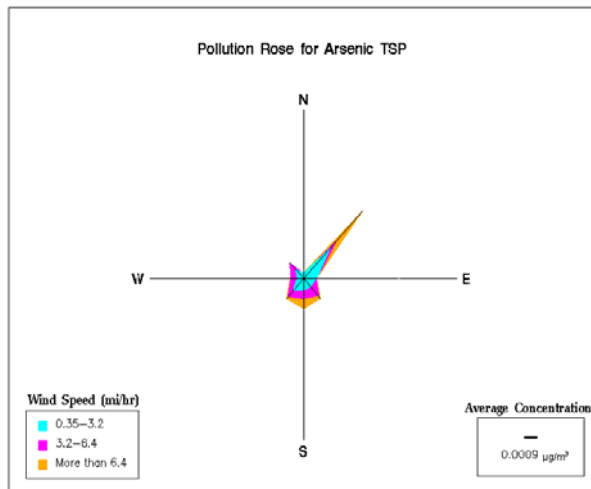Figure 4. Time series of daily arsenic TSP at AT monitoring site

Figure 5. Pollution rose for arsenic TSP at AT monitoring site

The pollution rose or other forms of representation of pollutant concentrations can also be plotted directly on a map of the area using GIS features. In this manner spatial distributions of AT concentrations may be visualized in spatial form. The above are just some examples of the types of spatial-temporal data summaries and presentations that we will utilize. Additional analyses and in-depth interpretation will be used to describe the full range of community-scale AT situation for Birmingham and Jefferson CO.

Two of the core sites were chosen in response to **specific community concerns (JCDH) of possible high AT exposure risk** in urban-(low-income) residential areas: the Sloss site near a large coke plant and the E. Thomas site close to high-motor-vehicle-traffic area. A characterization of the AT exposure at these two sites will be a second top-priority goal of the proposed project. The use of the pollution rose will be one appropriate analysis approach. The high temporal resolution of FTIR data will permit us to characterize the time scales of such exposures with considerable precision. The simultaneous measurements of both the concentrations and the wind information so close downwind of these dominant sources will also permit us to arrive at some quantitative sense of the corresponding AT emission rates. For such quantitative analyses of the impact of specific sources of special concern over neighborhood- to meso- scales, we will also apply source-oriented AQ models (see next paragraph); we will access the upper-air (radiosonde) wind data measured not very far away at the Birmingham municipal airport. For other sites impacted by emissions from multiple sources, we will resort to the application of receptor-modeling (next paragraph). The Sloss and E. Thomas data will be carefully analysed with a view to developing future projects aimed at reduction of risk from such concentrated emissions in populated areas.

Our team has strong capabilities and experience in both **source-oriented (UAH) and receptor-oriented (Battelle) modeling in diagnostic mode**, in conjunction with ambient measurements. The source-oriented models link emissions from specific known sources with downwind pollutant spatial-temporal concentration distributions through explicit simulation of dynamical and kinetic processes (e.g., transport and chemistry). In conjunction with ambient measurements, they can be used as doagnostic tools to infer emissions or downwind spatial-temporal concentration distributions. The UAH-LESchem (LES = Large Eddy Simulation) is a research-grade neighborhood-scale Eulerian model which can both resolve individual large turbulent eddies (~100 m) and include externally-supplied detailed chemical mechanism. The UAH-LRPM, on the other hand, is a more operational Lagrangian Reactive Plume Model, which uses plume dynamics simulated by the preprocessor UAH-PDM (Plume Dynamics Model).   The PDM-LRPM combination is a state-of-the-art lagrangian plume modeling system capable of simulating upto-mesoscale plume dynamics and kinetics (chemistry and removal processes) in both urban and rural environments (Gillani and Wu, 2003a). The PDM-LRPM system has been tested and applied extensively, and is also the building block of the Plume-in-Grid treatment in EPA's urban-regional modeling system, Models-3/CMAQ (Gillani and Godowich, 1999). The LES modeling, especially with chemistry, is in a relatively pioneering state in AQ applications (Gillani and Wu, 2003b). Receptor or source apportionment modeling methods (Henry, 1997) have

been developed to apportion observed ambient concentrations of pollutants into sources and/or source categories (without assuming anything about the possible sources other than consistent pollutant output). The primary data analysis tools we would use for source apportionment are UNMIX models and the Positive Matrix Factorization, PMF (Hopke, 2000) approach. Preliminary source apportionment would be done with UNMIX to establish an initial model for PMF. Final PMF model selection would be based on the overall chi-squared goodness-of-fit measure, evaluation of parameter-specific residuals, and within solution consistency of apportioned species masses. Our UAH and Battelle partners will perform such diagnostic model applications, as appropriate, to provide quantitative elucidation of the nature of AT pollution in the study area.

Our proposal also includes **a specific non-routine advanced technology - the FTIR** , which has a strong potential for routine operations for State/Local agencies and Tribes. In our FTIR design, we have integrated existing technologies to create a system which can not only provide in-situ continuous (resolution of minutes) AT concentration measurements with acceptable detection limits, but it has the added advantage that the chemical analysis is performed on-line at negligible cost compared to the enormous corresponding cost (and time delays) of the currently routinely used batch-mode methods which provide 24-hour average information, typically. Our FTIR can be evolved in the future to combine simultaneous measurements of both organic gases and aerosols with speciation. The FTIR will also significantly enhance the value of the study by filling in important data gaps of the core network in terms of spatial-temporal coverage.

Finally, our program of data analysis will **completely integrate the new AT measurements with the wealth of data of the existing criteria pollutants monitoring network**. In this manner, we will use the data of ozone, for example, to enrich our understanding of processes simultaneously affecting photochemical ATs (e.g., formaldehyde) also, and the speciated PM2.5 information of the existing program will provide a check for the particulate measurements of the AT program. The modeling will also include the simulation of ATs and ozone, for example, thus capitalizing on the rich database of ambient ozone measurements. We will also simply add the AT information to the existing highly-developed public outreach tools (e.g. website) already existing for Birmingham AQ. *We believe that our monitoring as well as data analysis plans are very strongly responsive to all of the selection criteria specified in the RFA.*

3.6 Task 6: Public Outreach
In the past three years, under funding from EPA's EMPACT program, JCDH and UAH have jointly created an outstanding website for public outreach, which currently presents near-real-time spatial and temporal information, including hourly concentration data of all continuously measured variables in the Birmingham criteria pollutants monitoring network (sites shown in Fig. 1) in very aesthetic graphical form. We will integrate the AT monitoring data into this website content by the beginning of the AT monitoring program. Links to the website will be made available to the general public through the JCDH, ADEM and UAH websites. The enhanced website will be launched by means of press releases and a media event at JCDH. In addition to the monitoring data, we will also include educational components aimed at public understanding of the nature and significance of the AT problem.

Our public outreach program will have other elements also, including communication through the local media. JCDH is a member of the AL Partners for Clean Air (APCA) in which local stakeholders collaborate to promote the local ozone action program. JCDH also conducts awareness and educational programs with a well-organized network of neighborhood associations, educational institutions, and many civic-social, business and environmental groups. We will integrate an AT component into all such activity also.

3.7 Task 7: Extend the In-state Partnership to Include ATs
 As part of the EMPACT-Birmingham program, an excellent in-state partnership has been established between JCDH, ADEM (AL Dep of Env Management) and UAH, thus linking state and local (Birmingham) environmental agencies with our state university, which has a nationally-recognized academic/research program in Atmospheric sciences. Generally, JCDH and ADEM perform the monitoring and regulatory functions, while UAH specializes in modeling and data analyses, and assists in public outreach. In this program, UAH will also develop the innovative FTIR system and train the JCDH personnel in its operation. The new AT program will provide us the ideal opportunity to continue and extend this very fruitful in-state collaboration, which has markedly improved Birmingham's ability to understand and control its air quality problems. As in EMPACT, UAH will also bring to our support the work of an outstanding specialist group from outside the state, in this case, the Battelle group.

3.8 Task 8: Plan for Program Sustainability and Evolution
We view the current proposed project as an opportunity to initiate a new worthwhile AQ activity in the Birmingham area. During the project, specific plans and funding initiatives will be developed to sustain and further develop the program. That is EPA's goal also. One area of program evolution, for example, will relate to the FTIR. We will explore the possibility of replacement in the future of the operationally very expensive batch-mode AT sampling and analysis process by continuous FTIR systems with built-in, very low-cost analysis. We will also explore the possible future extension of the FTIR application to appropriate aerosols, particularly speciated organic aerosols, which are particularly important in the Southeast. Worth sustaining also will be the integration of the monitoring and data management functions related to both the criteria pollutants and the AT.

PROJECT MANAGEMENT

Collaborating Institutions and Key Personnel JCDH will be the prime contractor, responsible for overall coordination and management of the program, as well as for the "core" monitoring, emissions and public outreach tasks. UAH will develop, maintain and manage the website; it will also be in charge of the data processing-management task and the data analysis task, the latter with the assistance of Battelle. UAH will also develop the FTIR system and its application, and will train JCDH personnel in its operation. Samuel Bell (JCDH meteorologist) will be the PI. He will also lead the public outreach program and will be assisted at JCDH by Randy Dillard (chemist, core monitoring), Corey Masuca (engineer, emissions) and others. Professor Noor Gillani will direct the UAH participation, playing the lead role in data analyses and modeling, and coordination with Battelle and JCDH. He has nearly 30 years of experience in air quality studies, including lead roles in major EPA field studies and their data management and analyses, including diagnostic modeling. He has served as a US Delegate to NATO/CCMS Air Pollution Pilot Program, as well as in advisory roles to EPA, DOE, EPRI, etc., and as member of the Science Teams of several major AQ research programs including SOS. He has also developed original AQ plume models, and his group developed the Plume-in-Grid module of EPA's Models-3/CMAQ regional modeling system. He led the UAH team in the Birmingham-EMPACT program which developed the EMPACT website. He will be assisted by David Bowdle (FTIR development and application), Benjamin Norris (website and data management), Jennifer Geary (website design), a Research Associate (data analysis) and a Research Technician (FTIR assembly). Dr. Steven Bortnick (AQ monitoring and modeling) will lead the Battelle team's participation in data analyses. Drs. Chet Spicer (atm.chemist) and Basil Coutant (source apportionment and receptor modeling) will serve as Senior Technical contacts; Dr. Jeff Lehman will serve as the Lead Statistician, and Dr. Shannon Stetzer will oversee data QA and management at Battelle, and SAS programming. Biodata of each of the key personnel are included in this proposal.

Project Schedule The Project will commence in September 2004. The first four months will be devoted to setting up the core monitoring sites and to assembly/testing of the FTIR. Also during this time, the emissions inventory task will get into gear, the necessary data processing codes and data management and analysis tools will be assembled and tested, and the website expansion will be developed. The monitoring program will last the full calendar year 2005; data analyses and assessments will commence as soon as the data begin to emerge and are processed, and will continue until the end of the Project in February 2006. The portable/roving FTIR will be deployed for an entire season (96 days, most probably the summer) at N. Birmingham, and during the remainder of 2005 will be deployed at up to seven other sites (including all the core sites) for periods of 36 days, typically.

Reporting On-going progress communications will be maintained with the EPA Project Officer as mutually appropriate. Brief written Progress Reports will be submitted to EPA within 30 days of the end of each Quarter, and a comprehensive Final Report will be submitted within 60 days after the end of the Project period.

Facilities and Equipment The existing full monitoring system of JCDH (17 monitoring sites) will be the base into which the AT monitoring facility will be integrated. This will include the data communications facilities. For data analyses and modeling at UAH, a 64-processor LINUX PC cluster with extensive memory and storage and software resources will be made available; a PC system will be acquired for this Project for the data processing and management functions. UAH also has fast internet connectivity to facilitate all outside electronic communications, including website access. Battelle's computing and other facilities, previously extensively used for AT data management and analysis projects, will also be available to the Project. Both UAH and Battelle also have a battery of related software, including SAS, ArcView, IDL, etc., and custom-developed analysis packages.

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