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Perimeter Air Monitoring for Litigation Avoidance During the Cleanup of Former MGP Sites

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INTRODUCTION

Since the late 1980s, the USEPA has had in place a rigorous approach to gathering good data during the investigation of contamination problems at hazardous waste sites, which is known as the data quality objective (DQO) process. [1] This process is supposed to be applied to data gathered for migration pathways (surface water, groundwater, air, and direct contact) during all investigation phases, ranging from initial site assessment to site remediation. The DQO process is an important tool used by project managers and planners to define the type, quality, and quantity of data needed to make defensible decisions.

However, the DQO process is seldom applied properly to data obtained for the air migration pathway during *any* phase of site cleanup. The result is that the monitoring programs typically designed and implemented are unable to achieve defined objectives. In the highly public arena of former manufactured gas plant (MGP) site cleanups, this design deficiency can create litigation risk because the maintenance of acceptable offsite exposure levels cannot be clearly demonstrated to the local community.

This paper describes the design of a perimeter air monitoring program for an MGP site cleanup which achieved the data quality objectives defined in the DQO process, and which minimized the risk of litigation. As the case study demonstrates, all significant data quality issues were satisfactorily addressed during the planning stage and the monitoring data conclusively evidenced that risk levels remained within acceptable ranges at all times. This paper also describes why the goal of collecting technically defensible air monitoring data for applications of this type is so rarely achieved.

BACKGROUND

From the mid-1880s through the early 1950s, manufactured gas plants (MGPs) were widely used for generating gas to meet heating and lighting needs in cities and towns throughout the United States. Methane and hydrogen were produced from the heating of coal and other ingredients in large brick ovens, and were stored in on-site tanks. With the discovery of large deposits of natural gas in the 1950s and the advent of natural gas pipelines, however, MGPs were rapidly abandoned. Today, the coal tars, light oils, and inorganic wastes typically found in the soil and groundwater around these plants are an environmental and public health concern. Some estimates place the number of MGP sites still awaiting cleanup in this country at 3,000 or more.

A properly engineered MGP site cleanup proceeds in a systematic fashion which minimizes the exceedances of risk levels due to contaminated soil. Such planning, together with cleanup durations on the order of weeks to a few months, in most cases, ensures that there are no exceedances of acceptable risk levels, including those due to air emissions.

The potential for exceedances of acceptable risk levels during the cleanup of MGP sites is generally less than during the remediation of hazardous waste sites, where contaminants of concern are often found at greater concentrations. However, there are three reasons why a site owner's risk of claims during an MGP site cleanup is nevertheless significant.

- **Proximity to Communities**
  Nearly all MGP sites are found in well-populated areas, as the existence of cities and towns was the main criteria for MGP siting in the first place. Anecdotally, the likelihood of claims is proportional to the number of potential claimants.

- **Perception of Risk Due to Odors**
  Coal tar is particularly odorous, owing largely to the presence of numerous polycyclic aromatic hydrocarbons, many of which have very low odor thresholds. People often equate odor with contamination, which creates a *perception* of risk during MGP site cleanups.

- **A Highly Visible Responding Party**
  Ownership of an MGP site, regardless of how long it has been abandoned, is usually easy to ascertain. The fact that the gas supply to the local community continued after the MGP was decommissioned means it is likely that the local utility company will be responding to the contamination issues. Most importantly, there is likely to be the perception that the local utility has "deep pockets" and is an easy target for a lawsuit. This is in stark contrast to the situation for Superfund sites where locating responsible parties can be an arduous task, often culminating in the discovery that the site owners cannot be identified or have since become bankrupt.

Because of potential claims for exceeding acceptable risk levels during MGP site cleanups, the DQO process should be followed properly. This is particularly challenging, however, because air is, historically, the most difficult contaminant migration pathway to characterize. The air migration pathway is a three-dimensional medium whose properties can change rapidly over time. Meteorological conditions such as wind speed, wind direction, and atmospheric stability greatly affect the concentrations of contaminants in the air.

Design of an effective sampling program in such a complex medium is so challenging that investigators seldom achieve the "data representativeness" necessary for meeting the DQO process purpose -- namely to support defensible site decisions. For this reason, it is not uncommon for regulatory agencies to incorporate "safety factors" into contaminant-exposure standards called "Applicable or Relevant and Appropriate Requirements" (ARARs) to account for uncertainties in the quality of monitoring data collected. The main difficulty stems from the use of point monitors, which provide contaminant information from discrete points in space and, often, time. This paper suggests an alternative, the *optical remote sensing* (ORS) approach, in order to obtain data about contaminants along an entire monitoring path. Use of a *path-integrated* concentration measurement, together with requisite onsite meteorological data, will provide data which satisfies the data quality objectives of the DQO process.

APPLICATION OF THE DQO PROCESS

The DQO process is an iterative, seven-step planning approach used in the collection of environmental data. It provides a systematic strategy for defining the criteria that a data-collection design should satisfy, including: when, where, and how to collect samples or measurements; determination of tolerable decision-error rates; and the number of samples or measurements which should be collected. By using this process during the investigation of contamination problems at hazardous waste sites, the project manager and planning team can develop a framework for addressing specific problems and determine sampling designs to support decision-making.

Following is a step-by-step overview of the general DQO process for the investigation of contamination problems at hazardous waste sites (during any phase of activity), [1] as well as how this process was recently applied to an ORS-based perimeter air monitoring program during the cleanup of a typical MGP site. [2]

The case study concerns the Shelby Street MGP site located in Bristol, Tennessee, owned by Atmos Energy Corporation. A removal action was performed by ENV America Inc. under the direction of Arcadis, Inc., Atmos Energy's oversight contractor, during a 9-day period in November 2004. Minnich and Scotto was retained by Atmos Energy to perform the perimeter air monitoring.

For each step of the DQO process, a generic statement of purpose and the resultant outputs are identified, followed by how the procedure was implemented for the case study.

Step 1. State the Problem

> The purpose of this step is to summarize the contamination problem requiring new environmental data, and to identify the resources available to resolve the problem. The outputs are: a description of the contamination problem in terms of its potential exposure scenarios (within its regulatory and programmatic context); and an estimate of the requisite budget, schedule, and personnel.

It had been determined that cleanup of the Shelby Street MGP site could result in air emissions, thereby creating the potential for exceedances of acceptable risk levels. Prior investigations showed that high concentrations of coal-tar by-products existed in two former tar wells and one spray pond. [3]

Atmos Energy wanted to ensure that acceptable risk levels were maintained during the entire Shelby Street removal action. In addition, Atmos Energy wished to minimize the risk of claims. Proposals for both traditional point-monitoring and innovative open-path approaches were sought.

A total of 15 target compounds were identified based on a thorough literature search: 14 volatile organic compounds (VOCs) or polycyclic aromatic hydrocarbons (PAHs), together with total inhalable particulates (PM-10) as a proxy for benzo(a) pyrene.* The gaseous target compounds (VOCs and PAHs) were: ammonia; benzene; m-, o-, and p-cresol; ethylbenzene; naphthalene; phenol; styrene; toluene; 1,2,4-trimethylbenzene; and m-, o-, and p-xylene.

Based on review of existing tax maps and results of an onsite visit, the principal receptors of concern were: employees working in the nearby County Court House (about 30 meters east of the site); Court House visitors and employees who parked their cars in a nearby lot and walked along the site perimeter to the building; and the general population (including children) who might congregate at the site perimeter.

Step 2. Identify the Decision

> The purpose of this step is to define the decision which requires new environmental data to address the contamination problem. The output is a decision statement or set of statements linking the principal study question to potential actions which will resolve the problem.

* The strategy for handling benzo(a)pyrene was outside the scope of this paper.

With respect to the air migration pathway, Atmos Energy had two concerns during the site cleanup: (a) ensuring that acceptable risk levels were maintained at all times throughout the downwind community; and (b) obtaining data to minimize potential future claims alleging exceedances of acceptable risks. Therefore, the principal study focus was, "Demonstrate that any release of airborne compounds during site cleanup activities does not exceed acceptable levels of risk."

Step 3. Identify Inputs to the Decision

> The purpose of this step is to identify the information required to support the decision, and to specify which inputs require new environmental measurements. The output is a list of informational inputs needed to resolve the decision statement together with the sources of that information, including new environmental measurements.

Information required to resolve the decision statement involved consideration of issues and concerns such as monitoring technology, monitoring methodology, "data quality indicators," and unacceptable risk.

Selection of Monitoring Technology
Because of the temporal and spatial variability in air emissions during MGP site cleanups, ORS-based "whole-plume" monitoring was determined to generate data of a quality adequate to demonstrate, in real time, that these emissions did not pose an unacceptable risk to human health.

Open-path Fourier-transform infrared (FTIR) or ultraviolet (UV) spectroscopy were identified as ORS technologies capable of detecting all target compound air emissions,* although each was determined to have its own advantages and potential drawbacks. Because of its versatility, open-path FTIR spectroscopy is more likely to facilitate identification of "unknown" compounds should they appear in the spectra. Open-path FTIR spectroscopy is also the only citable ORS-based analysis method -- USEPA Toxic Organic Compendium Method 16 (Method TO-16)[4] -- even though open-path UV spectroscopy has been successfully employed in many Superfund site remediations.

The advantages of open-path UV spectroscopy are a lower equipment cost (as the technology is inherently simpler), and lower minimum detection limits (MDLs) for most of the target compounds, which might be important in the assessment of unacceptable risk.

* Further, open-path FTIR and UV spectroscopy can monitor naphthalene, the controlling target compound, in real time.

Ultimately, the FTIR MDLs were determined to be adequate for all target compounds based on air dispersion modeling performed to assess offsite impacts under the range of meteorological conditions and source-beam-receptor configurations expected to occur. The prevailing judgment was that the somewhat higher cost of this technology was more than compensated for by its versatility and formal USEPA recognition.

Monitoring Methodology
The cross-sector-averaging technique was used in conjunction with open-path FTIR monitoring for the direct assessment of offsite contaminant exposure. Conceived of and employed by USEPA Region 7, [5] this technique involves collecting path-integrated, crosswind contaminant measurement data downwind of the source (concentration units of parts per million times meters, ppm-m, or milligrams per square meter, mg/m^2), and then dividing each concentration by the plume width (m) to yield a representative maximum impact along the FTIR spectrometer beam (ppm or mg/m^3). For this application, 10-minute-averaged data is optimal.

A dilution factor is then applied to the maximum beam impact in order to account for the increasing amount of contaminant "loss" due to atmospheric dispersion as the plume is advected toward the downwind receptor(s). The dilution factor is based on previously performed air dispersion modeling similar to that described above.

A complete treatment of plume-width selection, while beyond the scope of this paper, is described elsewhere.[6] Basically, however, selection of an appropriate width depends on three factors: (a) various properties of the plume (which are functions of atmospheric stability) as it is transported along the mean wind direction; (b) the distance between the source and the FTIR beam; and (c) the width of the source itself (e.g., excavation area or stockpiled material). It should be noted that the method for determining plume width always yields an approximation somewhat narrower than the actual plume; this is conservative, as the plume width appears in the denominator of the above point-concentration calculation.

Data Quality Indicators
Measurement performance and acceptance criteria are typically expressed in terms of data quality indicators (DQIs). [7] The principal indicators of data quality are precision, accuracy, representativeness, completeness, comparability, and sensitivity.

Measurement quality objectives (MQOs) are the acceptance thresholds or goals for the project's data and are usually based on the individual DQIs for each matrix and analyte group. These DQIs may be defined as follows:

- *Precision* - a measure of the reproducibility of analyses under a given set of conditions (quantitative)

- *Accuracy* - a measure of the bias which exists in a measurement method (quantitative)

- *Representativeness* - how well sampling data represent selected characteristics about the media or phenomenon being measured (qualitative)

- *Completeness* - a measure of the amount of valid data obtained from the measurement method compared to the amount of data required to meet the decision-maker needs (quantitative)

- *Comparability* - the degree to which one data set can be compared to another (qualitative)

- *Sensitivity* - the capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest -- typically defined in terms of MDL or practical quantitation limit (quantitative)

Following is the result of the DQI analysis. Method TO-16 yields a data precision of < 5% and a data accuracy of < 25%; these MQOs were judged adequate for the intended application. The actual data precision achieved for all open-path FTIR data collected during the project was ±1.56%, and the actual data accuracy achieved was −5.72%, well within the stated MQOs. This level of precision and accuracy, while typical for open-path FTIR spectroscopy, is much better than that generally achieved with point-monitoring techniques.

For data representativeness, the only criteria was that the plume had to be fully contained within the downwind FTIR beam, thus allowing the total crosswind contaminant burden to be measured. Use of a flat mirror to "bend" the beam around corners facilitated achievement of this MQO as long as there was a mean plume transport (i.e., wind). Data representativeness is *almost never* adequately addressed when traditional point monitoring is used during site cleanups; emissions are highly variable in space and time, and achievement of a sampling density necessary to ensure consistent plume measurement is clearly cost-prohibitive.

For data completeness, at least four 10-minute-averaged monitoring events were required every hour of site-disturbance activity.

For data comparability, an acceptable level of data representativeness was required thereby facilitating the correlation of offsite impacts with *in situ* treatment and removal activities. Actual program results showed this correlation to be very strong.

Unacceptable Risk

The means of assessing unacceptable risk involved formalizing a series of potential exposure scenarios[8] and defining associated ambient air acceptable concentrations (AAACs). For each compound, AAACs were defined for exposure durations of 1 hour and 8 hours per day over the course of the removal action (conservatively assumed at the time to be 6 weeks). It was determined there would be no potential adverse health impacts to the downwind community if the average ambient-air levels did not exceed these concentrations during these time periods.

A 1-hour exposure duration was applied to the general population (including children) at the site perimeter (fenceline), and addressed the exposure scenario of people parking their cars and walking to and from the nearby County Court House.

An 8-hour exposure duration was applied to individuals inside the Court House (the nearest offsite "sensitive receptors," at a distance of 30 meters from the nearest site perimeter), and addressed the exposure scenario of Court House employees or visitors being present for a normal 8-hour day inside the building. This exposure scenario was applied at all offsite locations 30 meters from the site perimeter, regardless of direction. Because the nearest sensitive receptors other than individuals in the Court House (i.e., residences) were more than 100 meters from the site, this was a very conservative approach.

The key to adequately addressing the principal study question was the development of a means to use the 10-minute-averaged data as a conservative proxy for achievement of the 1- and 8-hour-averaged AAACs (discussed in Step 5 below).

Step 4. Define the Study Boundaries

> The purpose of this step is to define the spatial and temporal boundaries that the data must represent to support the decision. The outputs are: a description of the characteristics which define the sampling population of interest; a description of the geographical limits of each environmental medium within which the investigation will be carried out; the time period in which samples will be taken and to which decisions will apply; the most appropriate scale of decision-making for each medium of concern; and a description of practical sampling constraints.

The study boundaries were clearly defined in both time and space. Temporally, the only concern involved the emissions generated during the cleanup itself; nevertheless, background monitoring was performed prior to initiation of cleanup activities to document emissions insignificance under baseline (undisturbed) conditions. Spatially, the study boundaries were clearly delineated during the prior investigations. [3]

Concerning the scale of decision-making, as discussed above, 10-minute-averaged monitoring data was chosen as an appropriate, conservative proxy for achieving the 1- and 8-hour-averaged AAACs described in Step 3.

Step 5. Develop a Decision Rule

> The purpose of this step is to develop a logical "if / then" statement defining the conditions which would cause the decision-maker to choose among alternative actions. The output is the "if / then" rule.

A three-part decision rule was developed for this project:

- A single action-level (AL) exceedance was cause for notifying responsible field personnel

- Two AL exceedances during any running 1-hour period was cause for suspending cleanup work and initiating appropriate mitigative measures

- Suspended cleanup work could not be resumed until two consecutive acceptable monitoring events occurred (i.e., no AL exceedances)

Information required to develop the decision rule involved consideration of issues and concerns such as AL development and field methodology.

AL Development
Action levels were established for all target compounds to ensure that the AAACs were maintained. An AL exceedance alerted onsite personnel that implementation of some type of mitigative measure might be necessary in order to keep ambient air concentrations within these acceptable ranges.

All ALs were defined as 10-minute-averaged values, and all "monitoring events" were precisely 10 minutes in duration. This time period was chosen based on statistical considerations in establishing appropriate atmospheric-stability-related values necessary for ongoing assessment of plume width. [6] Use of this convention ensured that, for any target compound, ambient air concentrations could be maintained at levels less than the corresponding acceptable concentration (either 1-hour- or 8-hour-averaged).

Given that 10 minutes affords ample opportunity to initiate mitigative measures, there was no need to set the AL concentrations any higher (i.e., more conservative) than the AAACs; accordingly, the AL concentrations were set equal to the AAACs.

This approach to cleanup-action monitoring is in contrast to programs based on typically employed, traditional point techniques -- where sample-integration times are on the order of hours or longer and adequate spatial data representativeness cannot be achieved. Further, as mentioned in the Background, this approach obviates the need for regulatory agencies to apply a "safety factor" (typically an order of magnitude) to account for data-quality uncertainties arising from the use of discrete monitors in an emissions environment continually changing in space and time.

Field Methodology
Excel-based input forms were used for each monitoring event. These forms were incorporated into a computerized data-management system which, upon entry of the requisite data, automatically calculated the maximum fenceline and offsite (sensitive-receptor) exposure and displayed this information, in real time, on corresponding output forms.

Effective in-field communication was integral to implementation of the decision rule. Atmos Energy developed a reliable communication protocol with the site manager so that necessary mitigative actions could be initiated as soon as the AL-exceedance criteria was met.

Step 6. Specify Limits on Decision Errors

> The purpose of this step is to specify quantitative, decision-rule performance criteria expressed as probability-based tolerance limits on potential errors in decision-making. The output is the site manager's tolerable decision limits based on consideration of the consequences of making an incorrect decision.

The development of probability-based tolerance limits for establishing performance goals in order to limit uncertainty in the collected data is often enormously challenging for any type of environmental monitoring or sampling program. A decision error occurs when the collected data leads the site manager to choose a response action different from what would have been chosen had there been access to "perfect data" or absolute truth. Sampling design error and measurement error are the main components of the "total study error," and may be defined as follows:

- *Sampling design error* - the error (variability) caused by the sample collection design, the number of samples, and the actual variability of the sample population over space and time

- *Measurement error* - the error (variability) caused by imperfections in the measurement and analysis system itself

Sampling Design Error
The development of a measurement program which yields statistically significant data can be so complicated that statisticians are frequently relied upon during the design stage (e.g., defining the nature and extent of soil contamination for subsequent remediation). For the air pathway, such an approach quickly becomes cost- and resource-prohibitive, and the result, more often than not, is a program that fails to achieve the data representativeness DQI.

Employment of the cross-sector-averaging technique actually led to a zero sampling design error, as long as the entire contaminant plume was contained within the beampath. The entire concept of probability-based tolerance limits ceased to exist, as all natural variations of the contaminant levels were captured during each monitoring event. This aspect of the path-integrated concentration in general, and the cross-sector-averaging technique in particular, is what best illustrates the enormous utility of the measurement technology.

Measurement Error
In general, random and systematic measurement errors are introduced in a measurement process during physical sample collection, sample handling, sample preparation, sample

analysis, and data reduction. Although measurement error can never be eliminated, only sample analysis and data reduction errors needed consideration in this program. Sample collection, handling, and preparation errors did not exist, as there were no samples *per se*.

The sample analysis error was assessed in the context of the data precision and accuracy, results of which were presented in Step 3. Precision was assessed using a NIST-traceable cylinder of carbon tetrafluoride (CF_4) introduced into the measurement path via the system's internal flow-through cell during all gaseous contaminant monitoring events. Accuracy was assessed prior to and at the end of each measurement day using a NIST-traceable surrogate gas (sulfur hexafluoride or SF_6), which was similarly introduced into the measurement path.

The primary sources of data-reduction error for this program involved tabulation of the FTIR and meteorological data, and subsequent input to the computerized data-management software used to continually assess maximum fenceline and offsite exposure. The algorithms used for determining cross-sector-averaged concentrations and dilution factors (based on air dispersion modeling) were validated prior to field application of the software.

The potential for data-entry errors was minimized, as most entries were periodically checked in the field. All entries comprising a monitoring event which resulted in an exposure of more than half the AL were double-checked and reviewed prior to notification of responsible onsite field personnel. This potential source of error will be eliminated in future programs of this type once efforts to automate the FTIR and meteorological data input, currently underway, are completed.

Step 7. Optimize the Design for Obtaining Data

The purpose of this step is to identify a resource-effective sampling and analysis design for generating data expected to satisfy the site manager's decision performance criteria (as specified in the preceding DQO process steps). The output is the optimal data-collection design, along with documentation of key assumptions.

A data-collection strategy based on the generation of path-integrated concentration data for the target compounds, together with the collection of requisite, onsite meteorological data, allowed for the design of a highly resource-effective monitoring program to satisfactorily address the decision rule (Step 5).

Three individuals were required in the field: the site manager, the FTIR operator, and a technician to enter the field data into the computerized data-management system. Upon completion of data-input automation, subsequent projects of this type will require only two field personnel.

SUMMARY OF RESULTS

Detailed program results are presented elsewhere [6, 9] and are not reproduced herein. There were a total of 324 monitoring events for 14 target compounds over the 9-day program. This yielded a total of 4,536 opportunities for AL exceedances at each receptor type (fenceline and sensitive).

In all, there were only 29 fenceline AL exceedances (24 for naphthalene and 5 for benzene) and 6 sensitive-receptor AL exceedances (all for naphthalene); there were no AL exceedances for any other target compound. The program results clearly demonstrated that acceptable risk levels were maintained at all times.

Because optical remote sensing is a "stand-off" technology, implementation of the perimeter monitoring program did not interfere with site-cleanup operations. Despite the 35 AL exceedances, initiation of mitigative measures was required only on Day 1, with virtually no impact to the overall project timetable. The daily schedules for excavation and offsite waste hauling were never compromised.

In fact, the air monitoring program quickly became an integral part of the overall site-management activities due to the ability to characterize offsite impacts, *in real time*, as a function of cleanup activity.

CONCLUSIONS

Design of effective perimeter air monitoring programs during the remediation of hazardous waste sites has, historically, posed a major challenge to the field investigator. The inability to satisfactorily address data representativeness requirements inherent in the DQO process has frequently led to fundamental monitoring design deficiencies and the subsequent collection of data that are simply unable to meet established project objectives. For former MGP sites, the potential consequences of such design deficiencies are significant -- as proximity to communities, perception of risk due to odors, and the presence of a highly visible responding party (local utility company) combine to create unique concerns with potential claims.

Optical remote sensing is a cost-effective, technically superior alternative to the traditional approach for meeting perimeter monitoring objectives during former MGP site cleanups. Generation of a path-integrated contaminant concentration affords the opportunity to actually eliminate all sampling design error, thus greatly simplifying field decision-making as all natural variations of the contaminant levels are captured during each monitoring event. Use of this technology enables the data representativeness requirement to be easily addressed, thus minimizing the potential for claims.

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