Summary

Papers in this publication are divided into nine sections: (1) General Topics, (2) Data Quality Assessment, (3) Ambient Air Measurements, (4) Ambient Water Measurements, (5) Source Measurements, (6) Discharge Monitoring, (7) Special Topics, (8) Reference Materials, and (9) Quality Assurance Management. The nine sections are intended to give some logic and continuity to the presentation of many papers covering the complex subject of quality assurance of environmental measurements. The following paragraphs summarize the papers from each of the sections.

General Topics

The General Topics section comprises two papers that provide the basic framework for the quality assurance subjects subsequently presented in this publication. Taylor addressed the question: what is Quality Assurance? He states that "quality assurance as described here . . . may be defined as those operations and procedures which are undertaken to provide measurement data of stated quality with a stated probability of being right. The measurement system must be in a state of statistical control in order to justify such a probability statement. This is attained by quality control procedures which reduce and maintain random and systematic errors within tolerable limits and quality assessment procedures which monitor the quality control procedures and evaluate the quality of the data produced."

The other paper in this section is by Stanley and Verner. It describes the mandatory quality assurance program of the U.S. Environmental Protection Agency (EPA). Essential elements of the program include developing and implementing QA program plans, QA project plans, and standard operating procedures; conducting audits of the capability and performance of measurement systems, and data quality; maintaining a mechanism for corrective actions; QA training; and frequent reports to management on the quality of data, program effectiveness, and problems. The goal of the QA program is to ensure that all data generated are of known, documented, and acceptable quality.

Data Quality Assessment

Papers in this section cover various quality assurance procedures essential to assessing data quality: statistical design for monitoring sources of environmental
contamination, which includes a method for determining sampling and measurement error; data quality achievability goals for environmental measurement systems; guidelines for assessing and reporting data quality; and the development of detailed quality assurance plans for cooperative environmental measurements to ensure documentation of data quality.

Liggett describes designs for studying pollution sources through measurement of the environmental contamination they produce which contain three parts. The first is the basis for separating the contamination of interest from the background. The second is an independent method for assessing the sampling and measurement error. The third is a laboratory protocol for making the measurements and reporting the results. This paper discusses the integration of these parts into an effective design and proposes an integrated design for monitoring the ground water around a waste management facility.

The next paper, by Mitchell et al, reviews a technical guidance document developed by the EPA to aid in the proper selection of environmental measurement methods and the setting of achievable data quality goals for environmental monitoring projects. The paper includes a brief discussion of the rationale and purpose of the document, limited reviews of the four designated measures of data quality (precision, accuracy, completeness, method detection limits), other data quality information, and examples of actual data listings from the document.

Finally, Brossman et al describe a comprehensive Quality Assurance Project/Work Plan Guidance document developed by the EPA Office of Water to meet QA requirements for a wide range of users and types of water quality monitoring tasks. Good quality assurance practice dictates that environmental measurement tasks be adequately conceived, documented, and executed so that the resulting data can be used with some definable degree of confidence. Formalization of sound quality assurance/quality control (QA/QC) procedures can help ensure control and documentation of data quality. However, unless such procedures are built into the standard documents and practices utilized to develop and administer environmental measurement tasks, they can become a marginally useful and burdensome requirement. Accordingly, the guidance document described here was developed to facilitate the incorporation of sound and useful QA/QC practices into state environmental measurement tasks performed with financial assistance from the EPA and/or mandated under EPA regulations. In order to ensure effective implementation of QA/QC requirements, this guidance combines the features of a QA Project Plan with a Work Plan.

**Ambient Air Measurements**

This section covers important aspects of quality assurance related to ambient air measurements. The first paper is by Beebe et al and addresses the quality control methods used to assure data quality after the data has been recorded. The quality assurance aspects of the Tennessee Valley Authority's (TVA) environmental (aerometric) data management program are described. The two major
elements associated with the validation of much of TVA's environmental data are (1) initial computer flagging of physically/chemically questionable and outlying data, and (2) analyst review and feedback to field technicians to implement corrective actions. Examples of these procedures as applied to aerometric data are discussed.

Fritts and Hanson describe data precision assessment of total suspended particulate (TSP) measurements from collocated samplers for two monitoring programs. This paper examines collocated sampling data and precision results from two TSP monitoring networks. Factors potentially contributing to observed differences in concentrations between collocated sampler pairs are assessed, including type of sampling equipment used, operator procedures, site location and configuration, meteorological conditions, and sources and types of particulate material being measured. The results of this evaluation are intended to help establish reasonable achievability goals for TSP data precision and to define key factors that should be considered both in operating collocated sampling programs and in evaluating the resultant data.

The last paper in this section discusses internal consistency checks as an excellent means of validating data obtained during field studies of ambient air particulate matter. Techniques discussed by Cadle include inspection of data for outliers, intersampler comparisons, and ion balance and mass balance techniques. The use of these methods is illustrated with data collected in a variety of field programs. It is concluded that internal consistency checks should be incorporated into the quality assurance program of all field studies.

### Ambient Water Measurements

Papers in this section describe quality assurance requirements for ambient water quality measurements. Hillman discusses the EPA's laboratory certification for those laboratories analyzing public drinking water. Essential elements of the program include on-site inspections of measurement methods and quality control, and evaluation of performance.

The next paper in this section, by Erdmann and Thomas, describes the quality assurance program of the U.S. Geological Survey (USGS). This program covers all USGS personnel and instruments nation-wide involved with the measurement of pH and specific conductance. Round-robin testing of unknown samples is used to identify analytical or operator problems and to suggest corrective actions.

Kramer and Baker describe an analytical and quality control program for determining currently used pesticides in surface water. Although this paper focuses on the analytical methods involved, some good quality control and data quality assessment procedures are noted.

Last, a quality assurance program for microbiological analyses of water is described in a paper by Bordner. The importance of microbiological examination of water in environmental protection efforts emphasizes the need to develop and implement quality assurance programs. The QA program is defined as the in-
Integration of intralaboratory and interlaboratory QC, standardized methods, written QA guidelines, standard reference materials, training courses, and on-site laboratory evaluations into a formal, coordinated effort to ensure valid analytical results. The accuracy and reliability of analytical results cannot be guaranteed if the standard operating procedures of the laboratory do not include an effective, ongoing QA program.

**Source Measurements**

This section addresses quality assurance related to measurement of air pollutants from sources. *McCain et al* describe quality assurance practices for field programs set up for the determination of particle size distributions in emissions from industrial sources. The authors feel that in addition to the normal QA requirements more levels of QA must be added. These include specifying and verifying protocols for withdrawing a representative sample from the gas stream; steps to minimize and correct for the effects of interferences; operating protocols to ensure that the sampling conditions fall within the constraints of the hardware being used; sampler preparation; sample handling; and record keeping. Problem areas addressed include: (1) traverse methodology; (2) the number of samples required to obtain a given confidence level in the results; (3) the selection of samplers and the choice of operational parameters such as sampling flow rate; (4) interferences, controls, and blanks; (5) sample recovery and handling; and (6) post-test verification. The use of measurement methods which have been collaboratively tested is critical to the success of environmental monitoring programs.

*Butler et al* discuss QA practices associated with collaboratively testing a method for measuring sulfur dioxide and carbon dioxide in stationary source emissions. The primary purpose of the collaborative test was to determine the precision, accuracy, and reliability of the method. However, this paper emphasizes the quality assurance practices used in the collaborative test and presents new QA data. For example, in addition to samples collected by the method, samples were collected as reference data using a second technique and a continuous monitor located at the same site. As a result of the QA, the collaborative test was one of the most successful conducted to date.

Quality assurance for sampling is one of the weakest links in most environmental monitoring programs. *Brisini*, in his paper, discusses an industry view of quality assurance for manual source sampling. The author objects to any QA program that creates a paper burden and is not readily acceptable at all levels within an organization. He goes on to describe a QA program for manual sampling for the Pennsylvania Electric Company. This relies heavily on standard operating procedures that are concise, explicit, and easy to follow. Also, the use of on-site audits is clearly seen as an asset to ensuring the collection of representation samples and generating data of known quality.

The last paper in this section is by *Colby and Picker*. It discusses the devel-
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Development of QA protocols to ensure generation of hazardous waste incineration efficiency data of known and documented quality. The QA protocols that are the subject of this presentation address the representativeness of samples and sample collection, the precision and accuracy of analytical methods and destruction efficiency calculations, and the documentation associated with establishing data quality. Emphasis is placed on those QA approaches that can be applied to data sets of limited size rather than on those normally associated with this type of study.

Discharge Monitoring

Papers presented in this section cover QA aspects of monitoring municipal and industrial wastewaters discharged into navigable waters. This type of environmental pollution is regulated by discharge permits issued under the National Pollutant Discharge Elimination System (NPDES) as mandated by the Clean Water Act. Each discharger (permittee) is required to sample and analyze its effluent and submit a Discharge Monitoring Report (DMR) to the state and/or EPA. Polvi et al describe EPA’s QA program for Discharge Monitoring Report activities. The overall objective of the DMR QA program is to assure the quality of NPDES self-monitoring data. The function of the program is to measure the analytical ability of laboratories serving NPDES permittees, to promote corrective follow-up actions where needed with the most efficient use of available resources, and to achieve good analytical and reporting capability.

The next paper is by Kopecky and Vogen and describes the QA program covering Wisconsin’s NPDES activities. The current program consists of operator certification, on-site inspections, check samples, and follow-up to inspections. Wisconsin is proposing a Laboratory Certification program which would certify that a laboratory is actually producing data meeting set standards of accuracy and precision, as opposed to conventional programs which certify a laboratory’s capability to produce accurate data.

Britton provides a fairly comprehensive discussion of the development of statistics and acceptance limits for conducting performance evaluation studies for laboratories participating in DMR activities. The paper discusses developing acceptance limits, estimating the study statistics, developing linear regressions from previous study statistics, and preparing performance evaluation reports. Experience in the conduct of an actual study of several thousand major discharges is also discussed.

A comprehensive description of one major industry’s experience with NPDES quality assurance requirements is presented by Fisher. The paper covers experience and response to current QA requirements; the development of QA guidelines for the paper and pulp industry based on a review of current QA practices; observed deficiencies in regulatory on-site inspections; problems in flow measurements and sampling; quality control of specific measurements; and recommendations for possible improvements in the various QA areas discussed.
Hoogheem and Woods follow with a discussion of Monsanto's Analytical Testing (MAT) program. The MAT program provides analytical standards to Monsanto manufacturing plants involved in analyzing discharges as required by NPDES permit conditions. Standards are prepared and supplied at concentration levels normally observed at each individual plant. Standards are prepared by Monsanto's Environmental Sciences Center (ESC) using EPA methods. Eleven standards are currently available, each in three concentrations. Standards are issued quarterly in a company internal round-robin program and/or on a per request basis. This part of Monsanto's QA program has demonstrated that plants can reliably and accurately analyze contaminants specified in NPDES permits.

The last paper in this section is by Campbell and Hillman. The authors describe the DMR QA program in a specific region, looking at the results of QA inspections, performance evaluations, and corrective actions with emphasis on follow-up. Facilities holding permits under NPDES have been sent two sets of audit samples to analyze for permit required parameters. EPA Region VIII permittees have performed on the average better than other permittees participating nationally in two DMR QA studies. Follow-up procedures on DMR QA performance studies include phone calls, letters, and inspections. Permittee performance has improved as a result of the follow-up activities.

Special Topics

This section presents papers covering various QA aspects of special topics of environmental interests that are not clearly categorized within the air or water medium. The first topic addresses meteorological measurements that impinge directly or indirectly on measures of environmental quality. Lockhart insists that a QA program for meteorological measurements must begin with a QA plan that identifies the purposes for which the measurements will be made. For example, assume a monitoring task where a one-year data set of hourly values of wind speed, wind direction, air temperature, relative humidity, and precipitation amount is needed to describe the air quality measurements being automatically recorded. The QA plan will define the accuracy needed for this task and will give the quality control tasks necessary to produce data of this accuracy. The plan will also address the auditing tasks necessary to assure that the data, in its final form, meet these requirements.

Next, Williams describes a QA program for the salmonella mammalian-microsome mutagenicity assays, more commonly known as the Ames test. This paper provides general and specific guidance for the development and implementation of a quality assurance program for Ames testing. The functions and responsibilities of an effective quality assurance program are outlined. The primary functions include development of standards based upon technically attainable criteria, assistance to participating laboratories in adopting those standards, and independent evaluation of the success of the laboratories in meeting those standards.
The growing concerns relative to acid rain emphasizes the importance of the next paper by Campbell and Scott covering QA aspects of acid precipitation measurements programs. High-level quality assurance procedures are required for these programs to standardize the diverse measurement methods in use and to determine the validity of differences in measurements widely separated in space and time. Both in-lab (quality control) and external (quality assurance) procedures are required. A complete QA program for acid precipitation measurements must address program objectives; site selection and operation; operator selection and training; sample collection, handling, and analyses; and data checking, storage, retrieval, and transmission. Relevant quality assurance data, including analytical detection limits, blank values, and the variability of replicate determinations, must be supplied with each data transmittal.

The next paper is by Handy et al and describes a QA program covering a study of methodology for monitoring man's total exposure to pollutants. Most environmental monitoring does not provide a measure of total human exposure to pollution. Standardized methodologies are needed for assessing human exposure to many types of toxic pollutants, particularly organics. A personal exposure monitoring program was carried out to field-test methodologies for sample collection and analysis. The basic study involved the collection of personal air, breath, and water samples. Quality assurance procedures were implemented during the sampling period and included exposing field controls and blanks and the collection of duplicates. The analysis of the air/breath collections on Tenax GC® and water samples were performed by gas chromatography/mass spectrometry and gas chromatography methods, respectively. Twenty-two volatile halogenated and aromatic compounds were selected as target compounds. Daily instrument performance and calibration checks were performed, and precision quality control charts were maintained. The analysis of performance audit samples was a major component of the quality assurance protocol.

Data derived from exposure of human subjects to air pollutants are a basis for setting air quality standards. It is important that the data be valid and defensible. The penultimate paper in this section is by Hackworth et al. They discuss the planning and design of a QA program for the EPA-funded controlled environmental laboratory (CEL) located in Chapel Hill, North Carolina. The purpose of the QA program has been to independently verify the quality of the data generated by the CEL and to assure the proper operation of CEL safety systems. The primary emphasis of the QA program was the development of auditing procedures. Owing to the highly specialized nature of the CEL facility, it was necessary to tailor each audit for the area of concern. Some areas required systems audits, that is, verifying that the CEL operator has successfully completed a required activity. Other areas called for performance auditing using established auditing techniques. Still other areas needed performance auditing using modifications of established techniques or development of totally new auditing procedures.
Finally, new biological reference materials—incorporated *in vivo* incorporated toxic metals in water hyacinth tissues—are described by Austin et al.

**Reference Materials**

Reference samples and materials are vital to the success of any QA/QC program. This section includes papers by various authors that describe the development, distribution, availability, and use of reference samples: the U.S. Geological Survey reference sample program using natural waters presented by Janzer; the Marine Analytical Chemistry Standards Program of Canada discussed by Berman et al; the NBS program of Standard Reference Samples for environmental measurements described by Alvarez; reference samples available from the radiation, pesticides, and hazardous waste programs at EPA–Las Vegas presented by Kantor and Laska; development and distribution of reference materials for ambient air measurements by Mitchell and Puzak; and, lastly, reference samples and materials for water and wastewater analyses by Winter. All the programs described contain elements of development, distribution, and use of samples for quality control and interlaboratory performance evaluations.

**Quality Assurance Management**

The last section of this publication comprises two papers on quality assurance management. The first paper is by Eggenberger and describes specific steps leading to the establishment of an environmental QA program in an analytical laboratory. Aspects of a model QA program that applies fundamental principles and methods to selected laboratory instrumentation and analytical protocols for the attainment of accurate, reliable results are discussed. Also included in the discussion are specific factors such as method validation, reference standards, certification, sample handling, security, documentation, and continuing data quality assessment.

The other paper in this section is by Aspila et al. The authors describe a QA program covering environmental data produced by over 50 laboratories that support the Canada-United States Great Lakes International Surveillance Program. The program includes the development and use of stable natural reference standards for waters, sediments, and fish in an interlaboratory comparison studies program. Interlaboratory studies include 10 to 15 stable natural samples that are analyzed for 10 to 15 constituents by 25 to 35 laboratories. Interlaboratory results for each sample are ranked and then laboratory measurement bias identified by the method of Youden. Results deviating significantly from the interlaboratory median values are flagged by the method of Clark. A laboratory specific report is then prepared and provided to each participating laboratory and is made available to report writers who must typically work with results from different laboratories. These quality assurance activities are constructive and effective. Remedial measures are taken to improve the laboratory measurement process.
Final Remarks

Quality assurance for environmental measurements is still in its infancy. The authors in this publication have greatly contributed to its growth.

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