Lesson 8

Identification And Treatment Of Outliers

Identification and Treatment of Outliers

Questions Answered in This Lesson

- What are outliers?
- What are five possible reasons for the existence of an outlier in a data set?
- Why do you need to identify and eliminate outliers from quality-control data?
- How are data initially screened?
- How do you use the Dixon Ratio and Grubbs T tests to identify outliers?

Questions Answered in This Lesson (cont.)

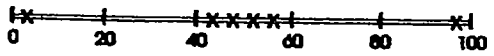
What are the significance-level critical values of the Dixon and Grubbs critical values tables?

What are the advantages and disadvantages of using either the Dixon Ratio Test or the Grubbs T Test?

How are control charts used to identify outliers?

What is the underlying assumption of the Dixon Ratio Test, the Grubbs T Test, and the control chart technique?

Identification and Treatment of Outliers



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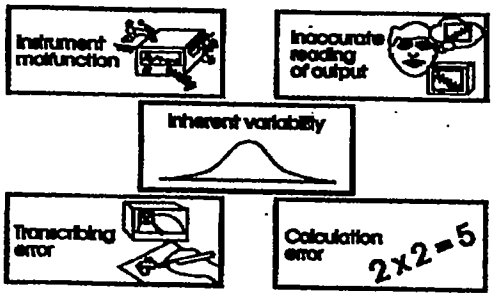
Causes of Outliers



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Need for Identification/ Elimination of Outliers

- Identification:
  - Indicates need for closer control
- Elimination:
  - Ensures analysis is valid
  - Ensures conclusions are correct

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Procedure for Identifying Outliers

- Screen data
- Subject suspect data to statistical tests

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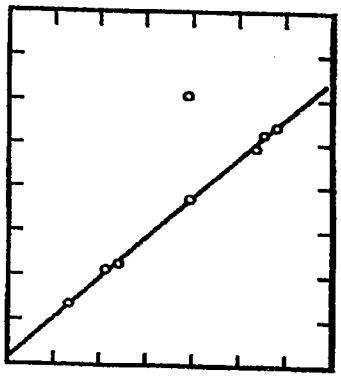

Use of Data Plots for Initial Screening

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Gas Concentration vs Voltage Output

Concentration (ppm)	Instrument reading (volts)
20.48	4.1490
15.36	3.5020
9.73	1.9820
4.87	0.9960
3.97	0.6370
0.00	0.0210

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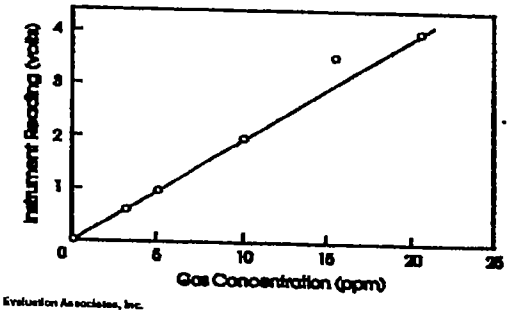
Graphing Gas Concentration vs Output Voltage



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Analyzing Duplicate Strips

Strip 1	Strip 2
11.1	11.5
8.8	8.8
30.0	31.8
8.5	8.9
5.7	5.4
6.8	6.9
3.6	3.0
1.7	1.8
20.1	19.0
24.8	23.4
14.8	15.2
5.3	5.3

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Difference (d) and Percentage Difference ($\%d$)

Strip	Strip 2	$\bar{x}$	d	$\%d$
11.1	11.5	11.3	-0.4	-0.5
8.8	8.8	8.7	0.2	2.3
30.0	31.8	30.9	-1.8	-5.8
8.5	8.9	8.7	-0.4	-4.6
5.7	5.4	5.55	0.3	5.4
6.8	6.9	6.85	-0.1	-1.5
3.6	3.0	3.3	0.6	18.2
1.7	1.8	1.75	-0.1	-5.7
20.1	19.0	19.55	1.1	5.6
24.8	23.4	24.0	1.2	5.0
14.8	15.2	14.9	-0.8	-4.0
5.3	5.3	5.3	0.0	0.0

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Statistical Outlier Tests

- Dixon Ratio Test
- Grubbs T Test
- Control Chart Technique

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Dixon Ratio Test Procedure

1. Arrange data in either ascending or descending order
2. Calculate a ratio
3. Compare ratio to Dixon table
4. Determine if suspect value is an outlier

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1 Arrange Data Values in Either Ascending or Descending Order

- If smallest data value is suspect:
  $x_1 \leq x_2 \leq x_3 \leq \ldots x_n$
- If largest data value is suspect:
  $x_1 \geq x_2 \geq x_3 \geq \ldots x_n$

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2 Calculate a Ratio

For sample sizes of 3 to 7 data values, use the equation:

$$r_{10} = \frac{x_1 - x_2}{x_1 - x_n}$$

A graphic representation is:

$$r_{10} = \overbrace{x_1 x_2 \ldots x_n}$$

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2 Calculate a Ratio (cont.)

For sample sizes of 8 to 10 data values, use the equation:

$$r_{11} = \frac{x_1 - x_2}{x_1 - x_{n-1}}$$

A graphic representation is:

$$r_{11} = \overbrace{x_1 x_2 \ldots x_{n-1}} x_n$$

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2 Calculate a Ratio (cont.)

For sample sizes of 11 to 13 data values, use the equation:

$$r_{21} = \frac{x_1 - x_3}{x_1 - x_{n-1}}$$

A graphic representation is:

$$r_{21} = \overbrace{x_1 x_2 x_3 \ldots x_{n-1}} x_n$$

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2 Calculate a Ratio (cont.)

For sample sizes of 14 to 25 data values, use the equation:

$$r_{22} = \frac{x_1 - x_3}{x_1 - x_{n-2}}$$

A graphic representation is:

$$r_{22} = \overbrace{x_1 x_2 x_3} \ldots \underbrace{x_{n-2} x_{n-1} x_n}$$

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3 Compare Ratio Value to Dixon Table of Critical Ratio Values

Significance Level

n	10%	5%	1%
3	.886	.941	.988
4	.679	.765	.889
5	.557	.642	.780
6	.482	.560	.698
7	.434	.507	.637
8	.479	.554	.683
9	.441	.512	.635
10	.409	.477	.597
11	.517	.576	.679
12	.490	.546	.642
13	.467	.521	.615

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3 Compare Ratio Value to Dixon Table of Critical Ratio Values (cont.)

Significance Level

n	10%	5%	1%
14	.492	.546	.641
15	.472	.525	.616
16	.454	.507	.595
17	.438	.490	.577
18	.424	.475	.561
19	.412	.462	.547
20	.401	.450	.535
21	.391	.440	.524
22	.382	.430	.514
23	.374	.421	.505
24	.367	.413	.497
25	.360	.406	.489

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4 A Suspect Value is an Outlier if the Calculated Ratio is Greater than the Critical Value

0.465	>	0.406
Calculated ratio value		Critical value

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Example Problem #1

Using the Dixon Ratio Test, determine if the data value 25.1 is an outlier at the 5% significance level, given the data values on the next slide

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Data Values

19.0	19.1	18.3	21.0
18.0	20.1	20.7	21.1
17.4	18.4	18.8	20.8
19.8	25.1	20.1	20.2
18.2	20.9	18.5	
20.4	23.3	21.8	
19.6	17.2	20.6	

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thru
real

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Two Kinds of Interlaboratory Tests

- Collaborative
- Performance

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Collaborative Tests

- Assess precision and accuracy of a new measurement method
- Specialized; rarely used

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Interlaboratory Performance Test

- Identifies biased labs (and/or analysts)
- Estimates "between laboratory" measurement method reproducibility

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Considerations in Planning the Interlaboratory Performance Test

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Selection of the Parameter To Be Tested

- Automated method—total
- Manual method—portion

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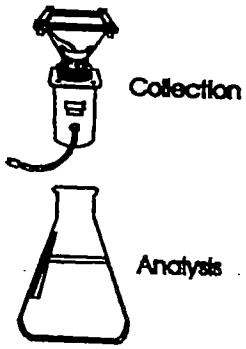
Selection of the Proper Sample



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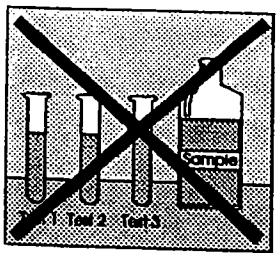
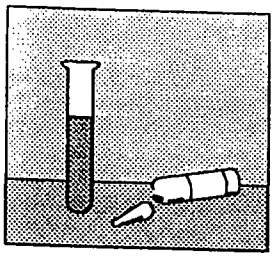
Sample Size





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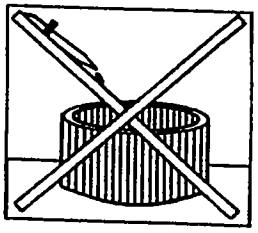
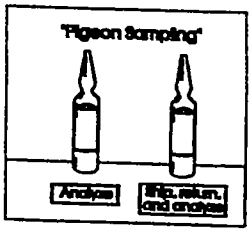
Sample Preparation—Ensure Uniformity, Stability





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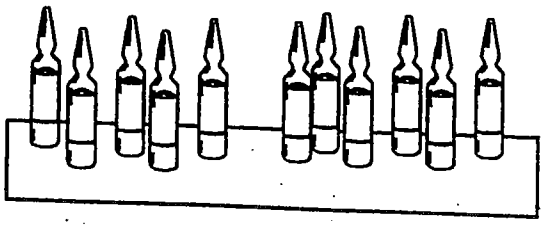
Sample Preparation—Evaluate Sample-to-Sample Variability



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Test Instructions

- Clear and complete
- Only one interpretation
- Specify handling—routine or special?
- Specify reporting form and units

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Selection of Method

- Inter-method lab variability—lab selects method
- Same-method lab variability—specify method

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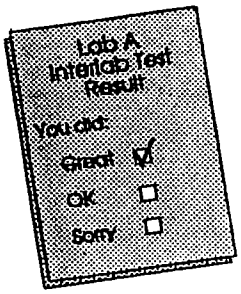
Report Results to the Labs



- Timely
- Confidential
- Recommend corrective action, if needed

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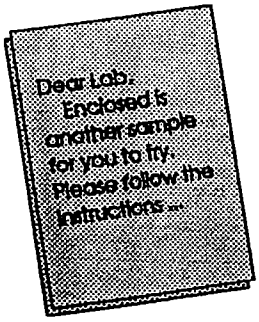
Follow-up



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Recap

- Select the parameter to be tested
- Select the sample
- Prepare the sample
- Prepare the instructions
- Provide feedback of results
- Specify corrective action
- Follow-up

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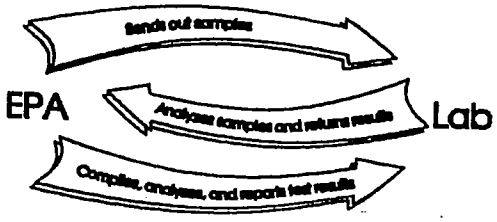
EPA Interlaboratory Performance Audit Program



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Hi-Vol Reference Flow (ReF) Device

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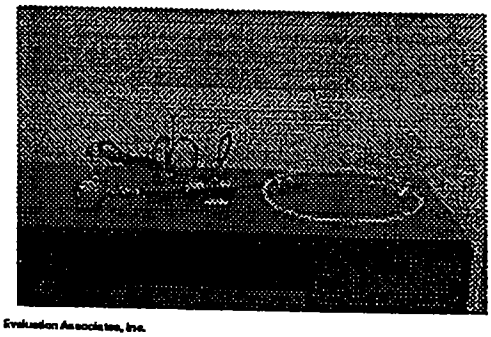
Dichotomous PM_{10} Sampler Audit Device



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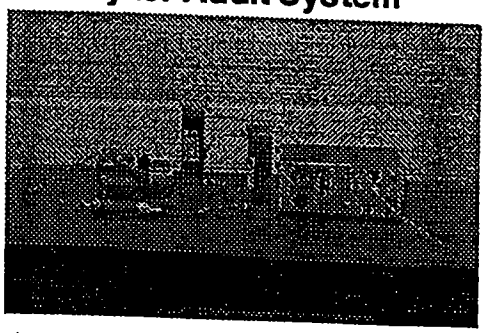
CO, SO_2, and NO_2 Analyzer Audit System



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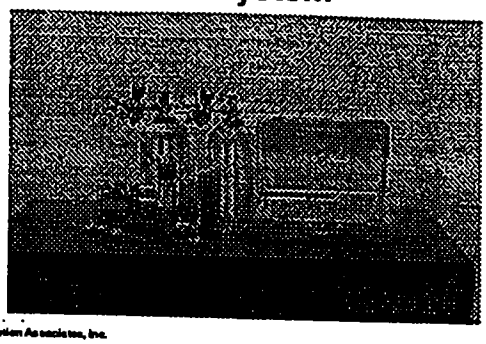
Ozone Analyzer Audit System



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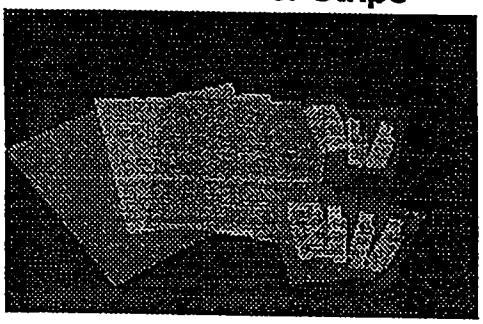
Lead, Sulfate, and Nitrate on Filter Strips



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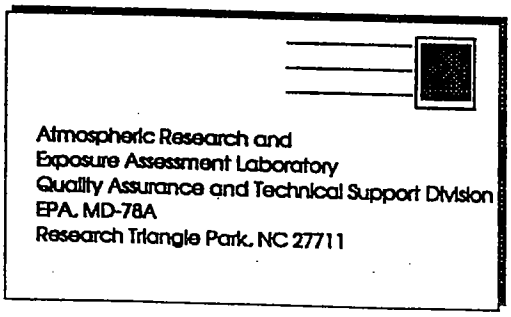
Write to:



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Calculate Percentage Difference

$$\% \text{ Difference} = \left(\frac{\text{Audit value} - \text{True value}}{\text{True value}}\right) 100$$

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Audit Acceptance Criteria

High-Volume/PM10 Sampler	±15% for 1 or more plates
Dichotomous Sampler (PM10)	±15% for 1 or more flows
Sulfate/Nitrate	±15% for 1 or more levels
Lead	±15% for 1 or more levels
Sulfur Dioxide	Mean absolute % difference <15%
Nitrogen Dioxide	Mean absolute % difference <15%
Ozone	Mean absolute % difference <15%
Carbon Monoxide	Mean absolute % difference <15%

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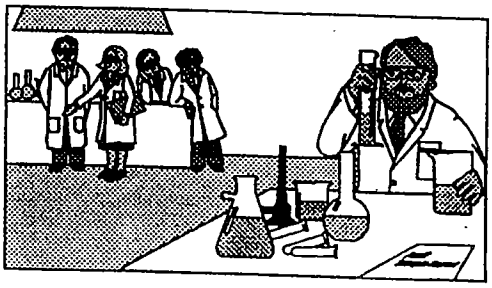
Why Are Audit Results Optimistic?



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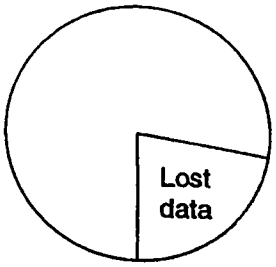

$$F_d = f \times B$$

Where:

F_d = lost data cost

f = % lost data

B = part of network budget associated with lost data

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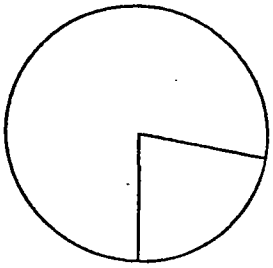
Prorate Personnel Salaries



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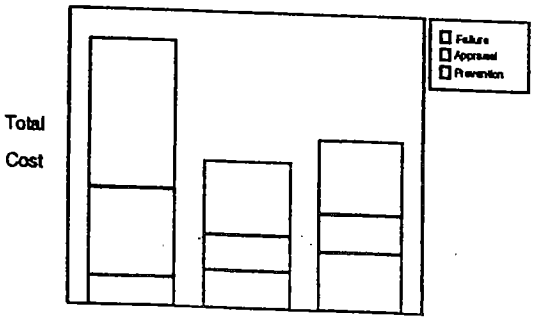
Cost Effectiveness



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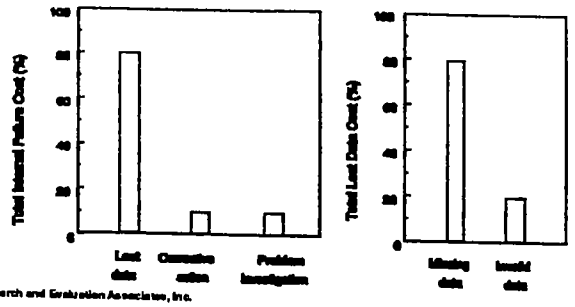
Pareto Analysis of Quality Cost Data



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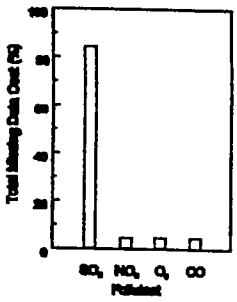
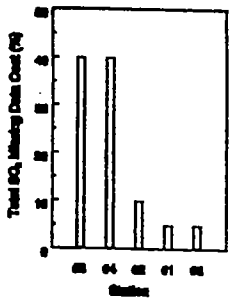
Pareto Analysis of Quality Cost Data (cont.)





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Quality Cost Reporting

- Data obtained from source documents
- Reports understandable at a glance
  - Data summarized
  - Graphs preferred

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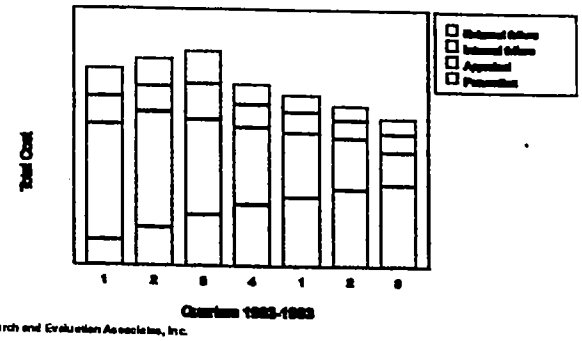
Quality Cost Trend Chart



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GUIDELINES FOR IMPLEMENTING A QUALITY COST SYSTEM FOR ENVIRONMENTAL MONITORING PROGRAMS

Presented at 73rd APCA Annual Meeting
and Exhibition in Montreal, Quebec,
Canada, June 1980

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GUIDELINES FOR IMPLEMENTING A QUALITY COST SYSTEM FOR ENVIRONMENTAL MONITORING PROGRAMS

Introduction

Program managers with Governmental agencies and industrial organizations involved in environmental measurement programs are concerned with overall program cost-effectiveness including total cost, data quality and timeliness. There are several costing techniques designed to aid the manager in monitoring and controlling program costs. One particular technique specifically applicable to the operational phase of a program is a quality cost system.

The objective of a quality cost system for an environmental monitoring program is to minimize the cost of those operational activities directed toward controlling data quality while maintaining an acceptable level of data quality. The basic concept of the quality cost system is to minimize total quality costs through proper allocation of planned expenditures for the prevention and appraisal efforts in order to control the unplanned correction costs. That is, the system is predicated on the idea that prevention is cheaper than correction.

There is no pre-set formula for determining the optimum mode of operation. Rather, the cost effectiveness of quality costs is optimized through an iterative process requiring a continuing analysis and evaluation effort. Maximum benefits are realized when the system is applied to a specific measurement method in a stable long term monitoring program. For example, a monitoring program with a fixed number of monitoring sites, scheduled to operate for a year or more, would be a desirable candidate for a quality cost system.

Quality costs for environmental monitoring systems have been treated by Rhodes and Hochheiser[1]. The purpose of this paper is to present guidelines for the implementation of a quality cost system. The contents of this paper are based on work performed by the Research Triangle Institute under contract to the U.S. Environmental Protection Agency[2].

Structuring of Quality Costs

The first step in developing a quality cost system is identifying the cost of quality-related activities, including all operational activities that affect data quality, and dividing them into the major cost categories.

Costs are divided into category, group, and activity. Category, the most general classification, refers to the standard cost subdivisions of prevention, appraisal, and failure. The category subdivision of costs provides the basic format of the quality cost system. Activity is the most specific classification and refers to the discrete operations for which costs should be determined. Similar types of activities are summarized in groups for purposes of discussion and reporting.

Cost Categories

The quality cost system structure provides a means for identification of quality-related activities and for organization of these activities into prevention, appraisal, and failure cost categories. These categories are defined as follows:

- Prevention Costs—Costs associated with planned activities whose purpose is to ensure the collection of data of acceptable quality and to prevent the generation of data of unacceptable quality.
- Appraisal Costs—Costs associated with measurement and evaluation of data quality. This includes the measurement and evaluation of materials, equipment, and processes used to obtain quality data.
- Failure Costs—Costs incurred directly by the monitoring agency or organization producing the failure (unacceptable data).

Cost Groups

Quality cost groups provide a means for subdividing the costs within each category into a small number of subcategories which eliminates the need for reporting quality costs on a specific activity basis. Although the groups listed below are common to all environmental measurement methods, the specific activities included in each group may differ between methods.

Groups within prevention costs. Prevention costs are subdivided into five groups:

- Planning and Documentation—Planning and documentation of procedures for all phases of the measurement process that may have an effect on data quality.
- Procurement Specification and Acceptance—Testing of equipment parts, materials, and services necessary for system operation. This includes the initial on-site review and performance test, if any.
- Training—Preparing or attending formal training programs, evaluation of training status of personnel, and informed on-the-job training.
- Preventive Maintenance—Equipment cleaning, lubrication, and parts replacement performed to prevent (rather than correct) failures.
- System Calibration—Calibration of the monitoring system, the frequency of which could be adjusted to improve the accuracy of the data being generated. This includes initial calibration and routine calibration checks and a protocol for tracing the calibration standards to primary standards.

Groups within appraisal costs. Appraisal costs are subdivided into four groups:

- Quality Control (QC) Measures—QC-related checks to evaluate measurement equipment performance and procedures.
- Audit Measures—Audit of measurement system performance by persons outside the normal operating personnel.
- Data Validation—Tests performed on processed data to assess its correctness.
- Quality Assurance (QA) Assessment and Reporting—Review, assessment, and reporting of QA activities.

Groups within failure costs. Under most quality cost systems, the failure category is subdivided into internal and external failure costs. Internal failure costs are those costs incurred directly by the agency or organization producing the failure.

Internal failure costs are subdivided into three groups:

- Problem Investigation—Efforts to determine the cause of poor data quality.
- Corrective Action—Cost of efforts to correct the cause of poor data quality, implementing solutions, and measures to prevent problem reoccurrence.
- Lost Data—The cost of efforts expended for data which was either invalidated or not captured (unacquired and/or unacceptable data). This cost is usually prorated from the total operational budget of the monitoring organization for the percentage of data lost.

External failure costs are associated with the use of poor quality data external to the monitoring organization or agency collecting the data. In air monitoring work these costs are significant but are difficult to systematically quantize. Therefore, this paper will only address failure costs internal to the monitoring agency. However, external failure costs are important and should be considered when making decisions on additional efforts necessary for increasing data quality or for the allocation of funds for resampling and/or reanalysis.

Examples of failure cost groups are:

- Enforcement actions—Cost of attempted enforcement actions lost due to questionable monitoring data.
- Industry—Expenditures by industry as a result of inappropriate or inadequate standards established with questionable data.
- Historical Data—Loss of data base used to determine trends and effectiveness of control measures.

Cost Activities

Examples of specific quality-related activities which affect data quality are presented in Table I. These activities are provided as a guide for implementation of a quality cost system for an air quality program utilizing continuous monitors. Uniformity across agencies and organizations in the selection of activities is desirable and encouraged, however, there are variations which may exist, particularly between monitoring agencies and industrial/research projects.

Agencies should make an effort to maintain uniformity regarding the placement of activities in the appropriate cost group and cost category. This will provide a basis for future "between agency" comparison and evaluation of quality cost systems.

Development and Implementation of the Quality Cost System

Guidelines are presented in this section for the development and implementation of a quality cost system. These cover planning the system, selecting applicable cost activities, identifying sources of quality cost data, tabulating, and reporting the cost data.

Planning

Implementation of a quality cost system need not be expensive and time consuming. It can be kept simple if existing data sources are used wherever possible. The importance of planning cannot be overemphasized. For example, implementation of the quality cost system will require close cooperation between the quality cost system manager and other managers or supervisors. Supervisors should be thoroughly briefed on quality cost system concepts, benefits, and goals.

System planning should include the following activities:

- Determining scope of the initial quality cost program.
- Setting objectives for the quality cost program.
- Evaluating existing cost data.
- Determining sources to be utilized for the cost data.
- Deciding on the report formats, distribution, and schedule.

To gain experience with quality cost system techniques, an initial pilot program could be developed for a single measurement method or project within the agency. The unit selected should be representative, i.e., exhibit expenditure for each cost category: prevention, appraisal, and failure. Once a working system for the initial effort has been established, a full-scale quality cost system can then be implemented.

Activity Selection

The first step for a given agency to implement a quality cost system is to prepare a detailed list of the quality-related activities most representative of the agencies monitoring operation and to assign these activities to the appropriate cost groups and cost categories. Worksheets and cost summaries for collecting and tabulating cost data for specific measurement methods will then need to be assigned and methods developed to accumulate the costs as easily as possible. Ultimately and most important is the analysis of the accumulated costs, discussed in the next section.

The general definitions of the cost groups and cost categories, presented in the previous section, are applicable to any measurement system. Specific activities contributing to these cost groups and categories, however, may vary significantly between agencies, depending on the scope of the cost system, magnitude of the monitoring network, parameters measured, and duration of the monitoring operation. The activities listed in Table I are provided as a guide only, and they are not considered to be inclusive of all quality-related activities. An agency may elect to add or delete certain activities from this list. It is important, however, for an agency to maintain uniformity regarding the cost groups and categories the activities are listed under. As indicated previously, this will provide a basis for future cost system comparison and evaluation.

Quality Cost Data Sources

Most accounting records do not contain cost data detailed enough to be directly useful to the operating quality cost system. Some further calculation is usually necessary to determine actual costs which may be entered on the worksheets. The cost of a given activity is usually estimated by prorating the person's charge rate by the percentage of time spent on that activity. A slightly rougher estimate can be made by using average charge rates for each position instead of the actual rates.

Failure costs are more difficult to quantize than either prevention or appraisal costs. The internal failure cost of lost data (unacquired and/or unacceptable data), for example, must be estimated from the total budget.

Cost Accumulation and Tabulation

Cost collection and tabulation methods should be kept simple and conducted within the framework of the agency's normal reporting format whenever possible. During initial system development, a manual approach will allow needed flexibility, whereas, automatic quality cost data tabulation would be complicated, since many of the quality-related activities are not typical in existing accounting systems. Automatic tabulation of costs may be practical after the basic quality cost system has been developed.

Also, an effective cost system does not require precise cost accounting. Reasonable cost estimates are adequate when actual cost records are not available.

Worksheets and summaries used to collect and tabulate the cost data should be designed to represent expenditures by activity.

Quality Cost Worksheets

Worksheets for collecting and tabulating quality cost data should be prepared for each specific measurement method. The worksheet should be designed to allow cost tabulation for each quality-related activity performed and to accomodate more than one personnel level per activity. In addition, activities should be organized into appropriate cost groups and cost categories so that when total costs are computed, they can be transferred directly to cost summaries later.

Quality Cost Analysis Techniques

Techniques for analyzing and evaluating cost data range from simple charts comparing the major cost categories to sophisticated mathematical models of the total program. Common techniques include trend analysis and Pareto analysis.

Trend analysis. Trend analysis compares present to past quality expenditures by category. A history of quality cost data, typically a minimum of 1-year, is required for trend evaluation. (An example is given in Figure 1 of the next section).

Cost categories are plotted within the time frame of the reporting period (usually quarterly). Costs are plotted either as total dollars (if the scope of the monitoring program is relatively constant) or as "normalized" dollars/data unit (if the scope may change). Groups and activities within the cost categories contributing the highest cost proportions are plotted separately.

Pareto analysis. Pareto analysis identifies the areas with greatest potential for quality improvement by:

- Listing factors and/or cost segments contributing to a problem area.
- Ranking factors according to magnitude of their contribution.
- Directing corrective action toward the largest contributor.

Pareto techniques may be used to analyze prevention, appraisal, or failure costs. They are most logically applied to the failure cost category, since the relative costs associated with activities in the failure category indicate the major source of data quality problems. Typically, relatively few contributors will account for most of the failure costs.[1,4] (An example is given in Figure 3 of the next section.)

Quality Cost Reports

Quality cost reports prepared and distributed at regular intervals should be brief and factual, consisting primarily of a summary discussion, a tabulated data summary, and a graphic representation of cost category relationships, trends, and data analysis. The summary discussion should emphasize new or continuing problem areas and progress achieved during the reporting period.

Written reports should be directed toward specific levels of management. Managers and supervisors receiving reports should be thoroughly briefed on the concepts, purpose, and potential benefits of a quality cost system, i.e., identification of quality-related problems, potential input into problem solution, and quality cost budgeting.

Quality Cost System Example

A hypothetical case history of a quality cost system is presented in this section. In this example, a cost system is developed for an agency operating sixteen sulfur dioxide monitoring stations. The stations are located within a 50-mile radius and each is equipped with a continuous sulfur dioxide monitor. The monitoring network has been in operation for 2 years.

The QA Coordinator is given the responsibility for implementing the quality cost system. The QA Coordinator plans the implementation of the pilot cost system. Planning for the system includes selecting cost activities, determining cost methods, and establishing procedures for maintaining the system.

To establish an historical basis quality costs are estimated for the past year. This allows for trend observation over an adequate period of time. These costs are shown (see Figure 1) and discussed in the following paragraphs.

Unacceptable data costs are a major cost group in the failure category. In order to establish the value of "lost data", the overall monitoring budget is determined from contracts, accounting documents, and other source documents. Table II summarizes total monitoring costs for the criteria pollutants and the sulfur dioxide costs are used in this example quality cost system. The cost data includes the maximum possible number of data units and cost per data unit.[5]

Quality-related costs are estimated for each quarter over the preceding year. The estimated costs are subject to the following considerations:

- Estimates of time spent by an operator performing a specific activity takes into account the capability of the operator to perform several activities simultaneously. For example, an operator performing daily analyzer zero/span will have time to simultaneously perform other duties while the analyzers stabilize to the zero/span inputs.
- The activities are performed by three personnel types: manager, supervisor, and operator. The cost per hour for each level is consistent with "Cost of Monitoring Air Quality in the United States."[5]

Analysis and evaluation of the collected cost data will determine several facts about the example agency's quality effort. The cost data should reflect the present status of the quality program, where major problem areas exist, and what immediate goals should be established.

A graph of the expenditures for each cost category is shown in Figure 2. Throughout the preceding year prevention costs were relatively small, appraisal costs were moderate, and failure costs were significant. Also, failure costs showed an increasing trend throughout the year.

A Pareto distribution of the failure costs (Figure 3) shows that the major cost contributor is "lost" data. The "lost" data cost represents over 80 percent of the total failure costs. Although the "lost" data cost represents less than 20 percent of the total data possible, the cost of this loss is significant.

An investigation determines the major cause of the problem to be a shortage of station operators. The workload of the one fulltime operator does not allow adequate time for an effective preventive maintenance program. The lack of proper preventive maintenance increases the frequency of analyzer/equipment failure resulting in an additional workload for the station operator, i.e., equipment repair.

The quality manager prepares a quality cost report covering the initial study results. The report presents several recommendations, including:

- Hire and train an additional operator.
- Increase prevention efforts for the monitoring operation.
- Reduce failure costs 50% by the end of the next reporting period.

During the following quarter, an additional operator was hired and trained. Preventive maintenance procedures were reviewed and modified as required. At the end of this reporting period, quality costs were collected, analyzed, and evaluated. The quality cost report covering this reporting period shows that failure costs were reduced 37%, prevention costs were increased 81% and appraisal costs increased 32%. A net decrease in total quality cost, amounting to $2,584 (11%) was experienced for the quarter as seen in Figure 1 when comparing the first quarter of 1979 with the fourth quarter of 1978.

The changes in category expenditures (Figure 2) reflect specific corrective measures initiated during the reporting period. These measures included hiring and training an additional operator and increasing the preventive maintenance effort.

Although the unacceptable data costs were decreased significantly, these costs are still excessive and a preliminary analysis of the last sulfur dioxide data indicates that additional effort in preventive maintenance is necessary to further reduce the networks operating costs.

TOTAL QUALITY COST SUMMARY
(Combined network costs, 1978-79)

COST GROUP	2nd Quarter	3rd Quarter	4th Quarter	1st Quarter
PREVENTION				
Planning & documentation	—	—	—	179
Procurement	—	—	—	179
Training	—	—	—	459
Preventive maintenance	588	559	587	1,046
System calibration and operation	1,254	1,317	1,386	1,713
TOTAL PREVENTION COSTS	1,842	1,876	1,973	3,576
APPRAISAL				
QC measures	768	806	742	1,631
Audits	1,308	1,508	1,470	1,913
Data validation	1,468	1,668	1,868	1,887
QA assessment & reporting	1,748	1,839	1,686	2,179
TOTAL APPRAISAL COSTS	5,292	5,821	5,766	7,610
FAILURE				
Problem investigation	1,579	1,886	1,760	704
Corrective action	1,361	1,334	1,365	546
Lost data (unacquired data)	12,430	13,893	13,162	9,506
TOTAL FAILURE COSTS	15,370	17,113	16,287	10,256
TOTAL QUALITY COSTS	22,504	24,810	24,026	21,442

MEASUREMENT BASES
Total program cost per quarter 48,304
Total data units per quarter 33,792

Figure 1. Total quality cost summary.

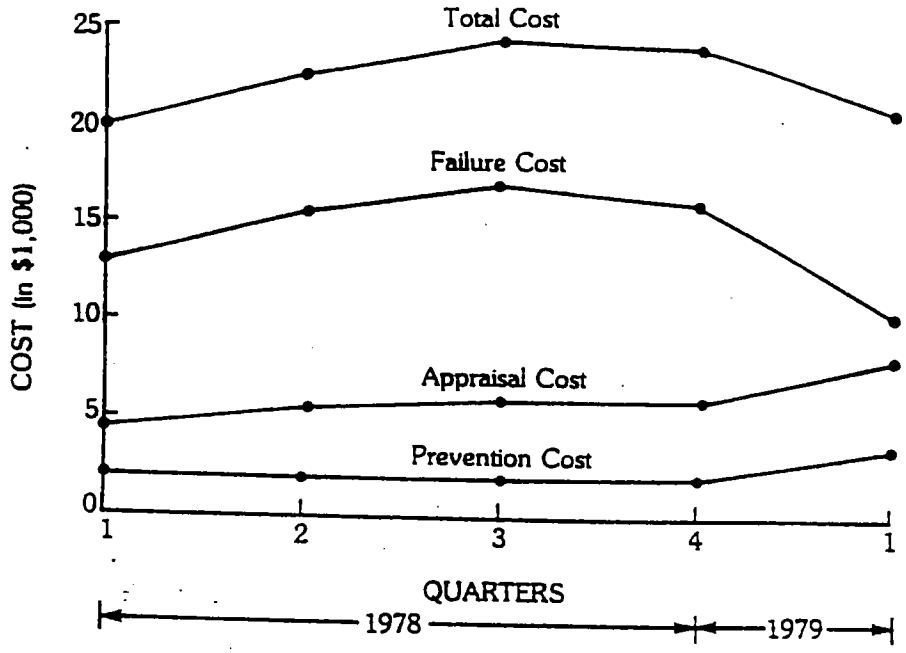

Figure 2. Quality cost trends.

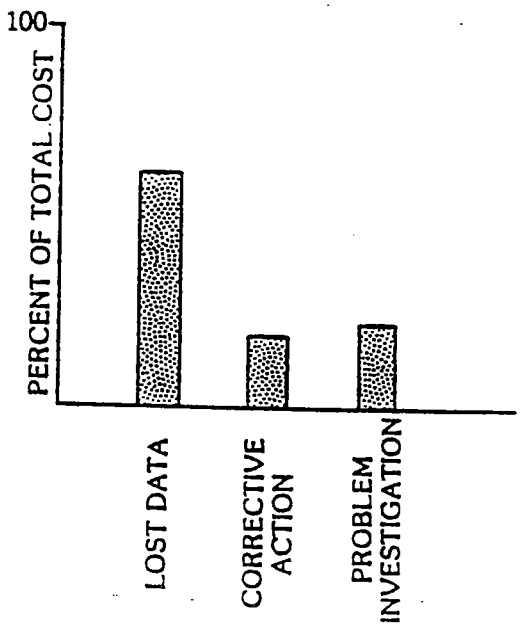

Figure 3. Failure cost distribution.

TABLE 1. EXAMPLE COST ACTIVITIES GUIDE FOR AMBIENT AIR MEASUREMENT METHODS

APPRAISAL COST CATEGORY	ACTIVITY	PREVENTION COST CATEGORY	ACTIVITY	FAILURE COST CATEGORY	ACTIVITY
QC Measures	Intercomparison of calibration teams. Operation of collocated samplers. Special activities performed by station operator strictly for obtaining data to evaluate accuracy and precision.	Planning and Documentation	Planning and preparation of: • Audit schedules and procedures • Operating standards • Apparatus configuration • Control procedures • Special tests • Operating procedures • Preventive maintenance procedures	Problem Investigation	Special tests and information collection to detect source and characteristics of problem Data and procedure review to identify problem area
Audits	Independent performance and system audits.	Procurement	Specification and acceptance testing of: • Calibration gases/devices • Equipment	Corrective Action	Cost of correcting data Cost of changing established procedures to prevent reoccurrence of problems
Data Validation	• Statistical evaluation of data • Review of data handling procedures • Comparison of data with historical data and data from nearby stations Review and evaluation of: • Control tests • Audit schemes • Audit results • Special interference tests	Training	Operator training/proficiency evaluation. Certification of calibration personnel and equipment.	Lost Data (unacquired and/or unacceptable data)	Estimated value of data which was lost or invalidated
QA Assessment and Reporting	Assessment of overall data quality. Generation of data quality reports. Maintenance of quality cost system records.	Preventive Maintenance	Maintenance of records, logs operation, calibration, and maintenance). Performance of preventive maintenance procedures.		
		System Calibration	Routine multipoint calibration of analyzers. Zero/span checks. Special checks on calibration system (voltage, temperature, variation, etc.)		

TABLE II. Total monitoring cost (dollars).

Pollutant	Annualized Total Cost Per Station	Maximum Data Units Per Station*	Cost Per Data Unit
CO	9,969	8448	1.18
SO_2	12,076	8448	1.43
O_3	8,713	8448	1.03
TSP	1,535	61	25.10
NO_2	8,757	8448	1.04
THC	9,231	8448	1.09
TOTAL FOR SO_2 = \$12,076 × 16 = \$193,216			

*Maximum data units for continuous analyzers based on total possible hourly averages per year.

Summary

The first step in implementing a quality cost system for an environmental monitoring program is to categorize quality-related activities into prevention, appraisal, and correction categories. An example listing for measurement methods involving continuous gaseous analyzers is given in this paper. Major items to be considered when implementing a system have been discussed along with an example quality cost system. Emphasis should be placed by management on preventive activities to decrease total cost of quality related activities.

References

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Lesson 17

Quality Assurance Guidance for PM2.5 Ambient Air Monitoring- Part I