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Project Summary

Evaluation of Control Chart Methodologies for RCRA Waste Sites

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This report is a discussion of decision rules relating to the monitoring of ground water at hazardous waste sites that are subject to regulation under the Resource Conservation and Recovery Act of 1976 (RCRA). The final rule for RCRA regulations 40CFR part 264 was published October 11, 1988 (53FR39720). Understanding the complexity of the monitoring problem and the diversity of RCRA sites, the final rule wisely allows the owner/operator to choose, conditioned on EPA approval, a site-specific "statistical procedure." Analysis-of-variance, tolerance intervals, prediction intervals, and control charts are included as acceptable methods for "statistical procedures." These methods are discussed to facilitate the choice of decision rules. A nested random-effects model for ground-water quality parameter measurement is suggested and decision procedures are developed in terms of that model. Particular attention is paid to the possible application of industrial quality control strategies to the ground-water monitoring problem. A decision procedure that changes over time as more information about well and aquifer characteristics accumulate is proposed. This procedure involves the use of outlier tests and of Shewhart-CUSUM quality control strategies.

This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Las Vegas, NV, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Under the Resource Conservation and Recovery Act of 1976 (RCRA), the U.S. Environmental Protection Agency has developed regulations for landfills, surface impoundments, waste piles, and land treatment units that are used to treat, store, or dispose of hazardous wastes. The regulations include requirements for the monitoring of ground water in the top aquifer below the hazardous waste site (HWS). This monitoring involves the drilling of background well(s) and compliance wells at the HWS, and the sampling and analysis of well water at regular time intervals to help determine whether leachate from the HWS has entered the aquifer. There are several as yet unsolved problems in this monitoring program. They include determination of appropriate methods for obtaining accurate measurements of some constituents such as volatile organics, specifications for well construction, detection and accommodation of shifting direction and rate of aquifer flow, and development of good decision rules based on measurements of water samples drawn from wells near the HWS for determining when additional regulatory action may be required. This paper discusses the problem of developing good decision rules and recommends that the development be based on a realistic model for the ground-water measurements. A nested random-effects model is suggested and statistical procedures based on that model are formulated and criticized. Industrial quality control strategies are considered in terms of their possible application to the ground-water monitoring decision problem.

Procedure

During the first year this project developed the appropriate components of variation model for the RCRA ground-water test problem. Such a model is the evaluation criterion for any proposed RCRA ground water test. The second year the implicit variance models assumed by the various proposed test strategies for the RCRA problem were explicitly derived and compared. The third year the most promising test procedure, control chart strategy, was evaluated against simulated data representing the most frequent RCRA data problems and different values of parameters critical to the test procedure.

Control chart strategy is evaluated on simulated "real world" data. Several available sets of "real world" data were examined for evaluating proposed RCRA statistical decision procedures. The sets all had one flaw for this use in that the state of the site (in-control or no leak, out-of-control or leak) was not known or recorded. Thus only simulated data sets could represent the desired state and relevant RCRA-type problems (multiple wells, correlated samples, etc.). The control chart strategy was evaluated for two factors related to the algorithms and five factors related to frequent statistical problems with environmental monitoring data. Each factor was simulated for both states (in-control, out-of-control). The factors evaluated in the design of the simulation experiments were (1) parameter estimates and (2) length of learning period for the Shewhart-CUSUM control chart strategy and RCRA-type data complications such as: (3) multiple wells, (4) correlated samples, (5) negatively skewed data (e.g., data overcorrected by transformation), (6) positively skewed data (e.g., monitoring data is often positively skewed, requiring transformation), and (7) multiple ground-water quality parameter data. The criteria of evaluation are long average-run-length for the in-control state and short average-run-length for the out-of-control state.

Summary and Conclusions

All statistical decision procedures are based on assumed measurement models. Decision procedures based on unrealistic models will not succeed in providing answers to ground-water monitoring decision problems, no matter how simple or elegant the procedures may be. It is essential that a realistic workable model for the measurements be formulated and used both in construction and evaluation of decision procedure. A nested random-effects model is presented to illustrate a model approach and to indicate the difficulties inherent in developing good statistical procedures for monitoring of ground-water quality. Obviously, no statistical measurement model is as complex as the system in nature, but the model for a decision procedure should be as reasonable and as simple as possible.

Any decision procedure, based on measurements of the quality of the ground water taken in each sampling period, where decisions are made at the end of each sampling period as to whether or not additional regulatory actions are required, is by definition a quality control strategy. In addition, for a quality control strategy, one is interested in the distribution of run lengths in both in-control and out-of-control situations. That is, a good decision procedure (quality control strategy) is one with large average in-control run lengths and small average out-of-control run lengths. Hence, consideration in comparing decision procedures for RCRA sites should be given to the distributions of their run lengths rather than to their probabilities of Type I and Type II errors on individual applications of the decision rule in each sampling period. (However, the two types of criteria are obviously not unrelated). In choosing a quality control scheme for use at RCRA sites it is reasonable to consider quality control schemes that have been used successfully in other settings, particularly in industrial settings.

The formulation of good decision procedures for determining when increased monitoring activity is needed at a hazardous waste site (HWS) is extremely difficult because of the high cost, slow acquisition, low precision, and multivariate nature of ground-water monitoring data along with system instability due to intrusions on the aquifer caused by man outside the HWS. The first three of these problems force the initiation of quality control strategies before good (highly precise) estimates of measurement distribution parameters can be obtained. With good estimates of the measurement distribution parameters, it is possible to mathematically derive the run-length distributions f various quality control strategie However, without these good estimates, is necessary to employ Monte Car techniques to estimate the distributic properties of run lengths when tl process is in-control (i.e., site is n leaking into aquifer and plume is passir through one or more well sites). Tl Monte Carlo analysis of the Shewhar CUSUM quality control technique indicates the type of results that can t obtained with this method and als indicates that the method is reasonab robust with respect to left-skewe non-normal probability distributions measurements. However, the techniqu is not robust with respect to lack independence between measurement in particular, its in-control run-leng characteristics are shortened by positi serial correlations.

The Monte Carlo simulation resul and methods discussed in this repo provide a basis for comparison an evaluation of all other decisio procedures, since similar Monte Car simulations can be performed on ar decision procedure to obtain estimates the run length distribution of such pr cedures.

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The complete report, entitled "Evaluation of Control Chart Methodologies for RCRA Waste Sites" (Order No. PB 89-138 416/AS; Cost: $13.95, subject to change) will be available only from:
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