A FIELD SAMPLING DESIGN AND METHOD OF STATISTICAL ANALYSIS TO DEFINE THE AREAL EXTENT OF PCB CONTAMINATION IN LOW-LEVEL WASTE POND SEDIMENTS

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ABSTRACT

This study demonstrates a cost-effective, site-specific field sampling program and statistical analysis scheme to estimate the areal extent of organic chemical contamination in low-level chemical and radioactive waste pond sediments. This approach was used to estimate the distribution of polychlorinated biphenyls (PCB's) in a Hanford area low-level waste pond. Using the statistical technique of kriging, a contour map of PCB concentrations in the pond was developed. The kriging analysis produced variance estimates about the contours, allowing evaluation of the estimated PCB concentrations and the ability to optimize placement of further sampling effort. Results of the study indicated that PCB concentrations in the pond sediments were generally less than 100 ppb.

INTRODUCTION

Management of known or suspected toxic waste sites, which can include confirmation of contamination, detecting contaminant migration or remedial action, requires a sampling strategy to define the areal extent of possible chemical contamination at those sites. When there are potential health risks to workers and the public at these sites, there is little margin for error in defining the extent of the waste plume. However, the high cost of chemical analyses requires that accurate estimates of contaminant concentrations be made with a minimum number of sample analyses. In this study we demonstrate a cost-effective, site specific field sampling scheme and method of statistical analysis to define the areal extent of contamination by organic chemicals in sediments of a low-level waste pond to meet these objectives. Our approach was applied in estimating the areal extent and concentrations of polychlorinated biphenyls (PCB's) in Gable Mountain Pond, a low-level waste pond on DOE's Hanford site in Richland, Washington. This study is providing Rockwell Hanford Operations and the Department of Energy with information needed for proper decommissioning and/or waste management decisions for the pond taking into account current federal regulation governing the disposal of PCB-containing wastes to the environment.

Polychlorinated biphenyls (PCB's) are constituents of insulating fluids used in electrical transformers and capacitors and are regulated compounds under Federal law (Toxic Substances Control Act, 1976). According to the law, substances containing greater than 50 ppm of PCB's must be contained and transported to approved disposal sites. PCB's have been disposed to the land of the Hanford site as a result of road oiling activities, accidental spillages, and other routine practices (R. G. Riley, L. A. Prohammer, D. A. Neitzel, R. M. Bean and J. M. Thomas, "Distribution of Polychlorinated Biphenyls (PCB's) in Surface Sediments of Gable Mountain Pond," Draft Report, United States Department of Energy). Any sediments in Gable Pond containing greater than 50 ppm of PCB's would require remedial action.

The sampling strategy for this study was designed, based on a statistical technique known as kriging, to produce a contour map of PCB concentrations in the pond, from the results of chemical analyses of sediment cores taken in the pond. Kriging is a weighted moving average technique for estimating functions describing spatially distributed phenomena, such as the distribution of organic contaminants in sediments (1). Kriging has important advantages over other contouring techniques for waste management because it produces contours with an associated measure of uncertainty. Therefore, areas in which the estimates of contaminant concentrations are poor can be defined, and additional sampling effort can be directed to those areas if more precise estimates are needed. This ability to optimize the placement of additional samples can result in substantial cost savings since sampling effort is minimized.

SITE DESCRIPTION

Gable Mountain Pond was constructed in the 200-North Area of DOE's Hanford site in Richland, Washington, to receive cooling water from the Purex Plant, where reactor fuels are processed (2). The pond is approximately 1 mile long and about 800 feet wide at its widest point (see Fig. 1A). There is a single inlet to the pond at the southeastern end, and water leaves the pond primarily through infiltration. There is an outlet channel in the small segment of the pond separated from the main pond by a dike road (Fig. 1A) that leads to an overflow area. The two pond sections are connected by a culvert under the dike road. The edges of the pond are heavily overgrown with pond weeds, primarily cattails and bulrushes, and trees, including willows and cottonwoods.

SAMPLING STRATEGY

Before the comprehensive sampling strategy was devised, a short preliminary site survey was conducted. The purpose of this survey was to exactly define the pond area, determine the depth to which we could reliably obtain sediment cores, test the sampling equipment and check for any sampling difficulties.

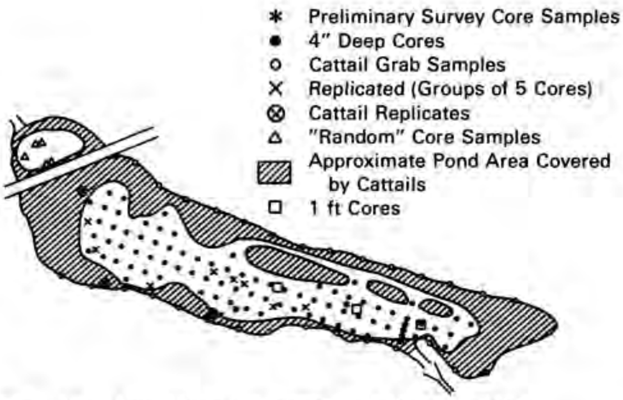

Fig. 1A. Locations of samples taken in Gable Mountain pond.

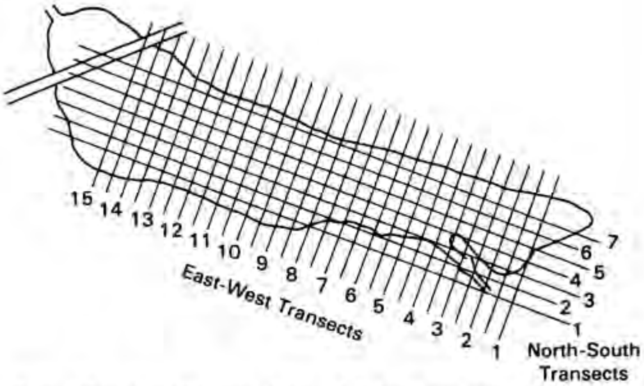

Fig. 1B. Sampling grid at Gable Mountain Pond.

The results of the preliminary survey indicated that the pond was lined with a hard-packed layer that our coring device could not penetrate, and covered with a sandy layer varying in thickness over the pond. This sandy layer was deepest in the southeastern area of the pond, and was practically nonexistent along the northern shore around the cattail islands (Fig. 1A). It was concluded that 4 in. was the maximum depth to which cores could be consistently obtained.

The edges of the pond were overgrown with cattails and contained sediment mixed with roots and decaying vegetation. These sediments varied in thickness from very thin to over 0.5 m. Because of the denseness of the weed roots in the sediment, it was determined that cores could not be taken in these areas.

During the comprehensive sampling, sediment cores were taken on a regular grid over the area of the pond; an arrangement well-suited for kriging analysis. Divers collected 79 sediment cores from a 150-ft grid covering the open water area of Gable pond (Fig. 1B). The north-south transects are numbered 1-7 south to north, and the east-west transects are numbered 1, 1.5, 2, 2.5, and so on through 15, east to west. The grid was measured in the field with a theodolite. The ends of selected grid transects were located with respect to permanent, surveyed wells on the site so that grid points could be relocated if necessary after the sampling was concluded. The locations of the samples we collected, based on the grid in Fig. 1B, are shown in Fig. 1A.

Cores were collected in 4 in. deep, 5 in. diameter PVC pipe sections. The ends of the pipes were beveled to provide cutting edges for easier insertion of the corers into the sediment. Each pipe section was fitted with two PVC pipe caps; one cap for each open end.

Additional samples were collected off of the main sampling grid. Five replicate cores were taken at each of nine randomly selected locations in the pond, to estimate the actual sampling variance (Fig. 1A). Twenty-nine grab samples were collected in the cattail regions at approximately equidistant intervals along the perimeter of the pond in about 30 cm of water. Each grab sample consisted of a sediment-root area cut loose from the bottom with a shovel and lifted by hand into a plastic bag. Five replicate grab samples were taken at each of three randomly selected locations in the cattails. Five "randomly" selected samples were taken in the small northwestern portion of the pond separated from the main pond by the dike road. Finally, three 1 ft cores were taken from the southwestern area of the pond, where both water and sediment were deepest.

CHEMICAL ANALYSIS

The samples collected during this study were analyzed in phases. First, half of the grid samples were analyzed, and the results mapped using the kriging technique. If the results indicated that more precise estimates were needed in any location, other samples in that area would be analyzed. However, in this case, the PCB concentrations were so low (relative to regulatory standards) that it was decided not to continue with further analyses.

Forty of the 79 grid sediment cores were chosen randomly from the grid for chemical analysis. Previous results had indicated that PCB's were concentrated in the surface sediment (R. G. Riley, R. M. Bean, R. E. Fitzner, D. A. Neitzel and W. H. Rickard, "A Preliminary Survey of Polychlorinated Biphenyls in Aquatic Habitats and Great Blue Heron on the Hanford Site, Draft Report, United States Department of Energy). Therefore, a 100 g subsample from the top 5 cm of each of the 40 samples was analyzed for PCB content.

The analytical method consisted of an exhaustive Soxhlet extraction of the wet sediment subsample with an azeotropic mixture of benzene-methanol, concentrating the extract with hexane and removing interfering sulfur by shaking with metallic mercury, followed by electron capture GC analysis to quantify the PCB present.

RESULTS

Figure 1 shows the locations of the 40 samples that were chemically analyzed, and the PCB concentration contours produced by the kriging analysis. All samples, with one exception, contained the specific PCB Arochlor 1260. No other PCB mixture was found. Only one sample, located between east-west transects 2 and 3 and on north-south transect 5 (Fig. 1B) contained a less than detectable level of PCB's. None of the 40 samples analyzed contained as much as 1 ppm of PCB's. Because of these low observed concentrations, no other samples were chemically analyzed.

Figure 2 also shows the 20, 40, 60, 80 and 100 ppb PCB's concentration contours in Gable pond surface sediments. The dotted line around the 100 ppb contour illustrates the +2 standard deviation error contour in this concentration.

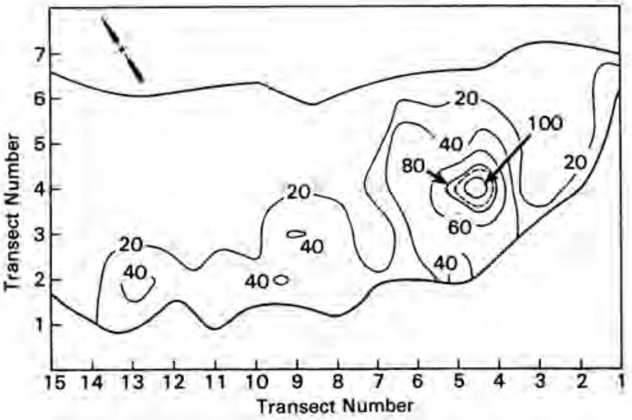

Fig. 2. PCB concentration contours (ppb) in Gable Mountain pond produced by kriging.

When PCB concentrations are close to or above regulatory limits, the size of such confidence bands can be used to show where additional samples should be taken in order to attain any required precision.

The distribution of PCB's in the pond (Fig. 2) is consistent with the hypothesis that they entered the pond primarily through the inlet pipe and spread along the length of the pond in an westerly direction. One disproportionately high concentration was found in the southwestern area of the pond, on east-west transect 13 and north-south transect 2 (Fig. 2). This could have been a separate input to the pond, or an area in which the PCB's accumulated due to the geology or hydrology of the pond. Visual comparison of the estimated PCB distribution with the water depth and sediment maps constructed during the preliminary pond survey did not indicate any relationship between PCB concentrations and these two factors.

SUMMARY

This study demonstrates a site-specific cost-effective method to determine the extent of organic contamination in low-level chemical and radioactive waste pond sediments that is easily applied in the field. Using the technique of kriging, a contour map of PCB concentrations and respective variance estimates was produced. The results could be used to optimize the placement of further samples, and thereby minimize wasted sampling effort. Locating the sampling grid in the pond could be done accurately with a theodolite. The grid was located with respect to permanent landmarks so that areas on the grid could be relocated if necessary after the sampling was concluded. This study also demonstrated strategies for sampling in areas that could not be sampled on the main sampling grid.

Cost effective application of this approach to larger and more complex site situations will require: 1) determining optimal combinations of field sampling and laboratory compositing schemes; 2) investigating different grid shapes and spacings; and 3) the use of double sampling, a method of reducing costs while retaining precision of results by using inexpensive analytical techniques calibrated by a small number of more expensive, more precise analyses.

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