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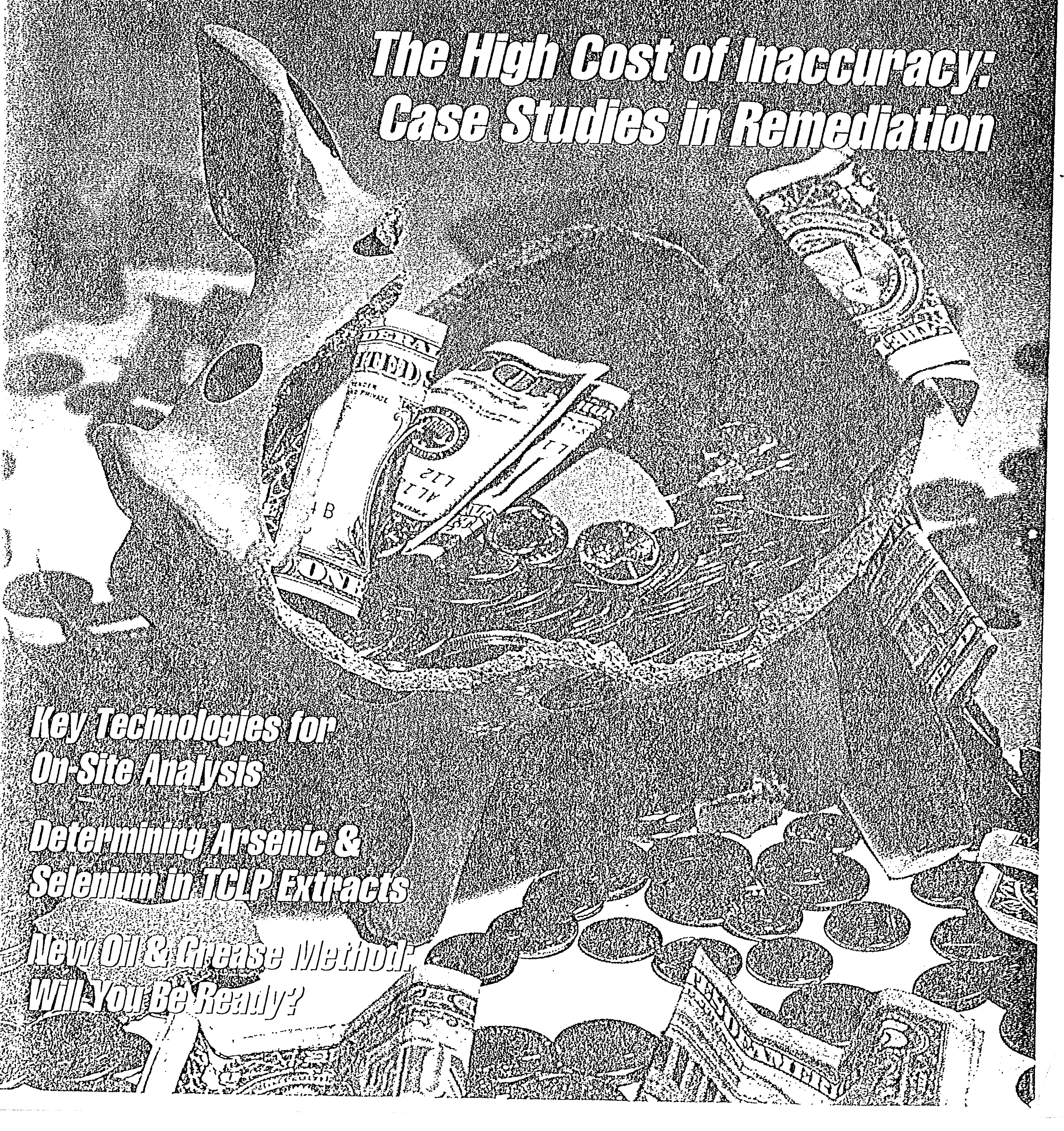
ENVIRONMENTAL Testing & Analysis

The High Cost of Inaccuracy: Case Studies in Remediation



Key Technologies for On-Site Analysis

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Perception and Reality

These case studies show some eyebrow-raising discrepancies between estimated contamination levels and the actual levels measured at the point of remediation.

By Emma P. Popek, Ph.D., and Garabet H. Kassakhian, Ph.D.

Remediation action planning is frequently based upon existing chemical data generated during site investigation (SI) studies, which usually include such elements as a record search, planning document preparation, sampling and analysis, data validation and interpretation, and reporting and review by the appropriate regulatory agencies. One might assume that this kind of effort would produce reliable information of sufficient volume to form the foundation for a remediation action plan. However, remediation action case histories have, in fact, proved the opposite: The perception of site conditions based upon site investigation findings does *not* reflect reality. Use of SI data invariably leads to either underestimating or overestimating the extent of contamination, sometimes on an alarming scale. In either case, ramifications may be substantial with respect to remediation budgets and public perception of the environmental industry.

What's the Problem?

During evaluation of environmental data quality by application of the PARCC parameters–precision, accuracy, representativeness, completeness, and comparability–the criterion of "representativeness" is often overlooked or misunderstood. According to the U.S. Environmental Protection Agency (EPA), representativeness is "the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition."[1] Representativeness is a qualitative parameter that depends on proper design of the sampling program.[2,3] The planners of remediation investigations/feasibility studies (RI/FS) have historically understood representativeness as narrowly relating only to parameter variation at a sampling point, thus placing more emphasis on accuracy, precision and completeness of chemical data.

The data may be accurate, precise and complete, but if they are not representative of site conditions, they become useless or even financially damaging. Principal reasons for underestimating or overestimating the extent of contamination usually originate from improper sampling and analysis design, including:

- Nonrepresentative samples analyzed for the correct contaminants
- Representative samples analyzed for the incorrect contaminants
- Nonrepresentative samples analyzed for the incorrect contaminants

All three of these situations present a distorted view of the site under investigation and are equally useless for planning remediation activities.

In spite of the fact that through the years the environmental industry has accumulated significant experience in RI/FS, one review report shows that in the past, environmental consultants had a poor understanding of, or ignored, the data quality objective (DQO) process.[4,5] In their work plans, RI/FS firms adhered to strict analytical protocols and data validation to achieve the goals for the data quality indicators, rather than focus on the overall project objectives and the means to fulfill them, such as understanding the intended use of the data; using screening techniques; developing representative sampling designs; or by statistically evaluating the collected data.

During contract negotiations, these firms were forced to reduce the number of samples and sampling locations, while substituting the required analyses with less expensive and thoroughly irrelevant tests. In one instance that occurred in 1996, previous SI studies indicated that a particular site was contaminated with selected semivolatile organic contaminants (SVOCs), as determined by using EPA Method SW 8270, gas chromatography/mass spectrometry (GC/MS). During Phase II of the same investigation, budget cuts reduced the number of samples from a projected 200 to 39, and planners substituted SW 8015 Modified, the nonselective Diesel Range Organics, as the method of choice.

During budget negotiations, quality assurance/quality control (QA/QC) was the preferred target of "reduction in scope" cutbacks by the project managers and contracting personnel of the negotiating parties. It is obvious that many of the sampling and analytical plans were prepared by engineers and geologists without a chemist's input or participation. Chemists who validated the data did not take part in project planning or execution, and did not assist in the interpretation of the data for project decisions. In addition, during the review of the project work plans, regulatory agencies often compromised in order to get a modicum of work done. However, reductions in the comprehensiveness of the field investigation, due to budget cuts, schedule-driven approval of incomplete plans, and superficial, protocol-oriented reviews by technically unqualified agency personnel, all often come back to haunt the stakeholders at remediation time.

The following case studies clearly illustrate the need for more effective site characterization sampling, as well as for an analytical approach that will generate representative and usable chemical data.

Case Study I: Pesticide Shop at a Former U.S. Military Installation

Investigation. A small building had been used to store, mix and dispense pesticides for mosquito control. During site investigation, the RI contractor collected four judgment surface samples for Contract Laboratory Program (CLP) organochlorine pesticides and polychlorinated biphenyl (PCB) analysis. The pesticides detected in the soil were DDT and DDE at concentrations ranging from 0.07 mg/kg to 2.6 mg/kg. Aroclor 1260 was detected in one of the samples at a concentration of 1.7 mg/kg. Based on these data, the RI contractor recommended removal of approximately 75 cubic yards of contaminated surface soil. Site-specific cleanup levels were as follows: DDT and DDE at a concentration of 1 mg/kg, and PCBs at concentrations of 1 mg/kg for the upper 4 feet of the subsurface and 25 mg/kg for the soil at 4 feet below ground surface (bgs).

Remediation. In order to better define excavation boundaries, the remediation contractor conducted a thorough surface delineation at the site prior to excavation. A mobile laboratory operated by this contractor developed and validated a screening analytical method for DDT and its metabolites. This screening method, which was based on EPA Method SW 8080 with relaxed QC acceptability criteria, produced quantitative data of known quality. The PCB screening was conducted using immunoassay kits, with detection limits of 1 mg/kg and 25 mg/kg.

Due to the low mobility of the contaminants of concern in the subsurface and based on the history of site use, the remediation contractor selected the judgment sampling strategy. Sample locations were initially placed in the areas where the RI contractor detected elevated concentrations of contaminants. Further delineation proceeded laterally to the depth of 4 feet. A total of 60 samples were collected and screened for DDT and DDE. Table 1 summarizes the results of the DDT screening.

The remediation contractor also screened for PCBs, collecting a total of 11 surface samples taken from the area of previous PCB detection by the RI contractor. Five of 11 surface samples showed PCB concentrations above 1 mg/kg, and the concentrations of PCBs in three of these samples exceeded 25 mg/kg. Four samples collected at the depth of 4 feet bgs did not contain PCB contamination above the concentration of 1 mg/kg.

Excavation of contaminated soil was guided by the results of screening analyses, with contaminated soil selectively removed from the "hot spot" areas until the cleanup levels had been reached. Confirmation analysis of 136 samples was conducted by an off-site laboratory that used the CLP analytical protocol. *Based on results of field screening, a total of 668 cubic yards of DDT and PCB contaminated soil were removed from the site, compared to 75 cubic yards originally estimated by the RI contractor.*

There were 10 sites at this military installation identified by the RI contractor as having limited surface contamination with organochlorine pesticides and PCBs. The RI contractor projected that a total of 735 cubic yards of contaminated soil would be removed from all sites and incinerated. Based on accurate contaminant delineation, the remediation contractor removed a total of 2,300 cubic yards of contaminated soil. The client reviewed the project budget and ruled out incineration as a disposal option due to prohibitively high costs. Instead, after conducting a treatability study, the remediation contractor carried out a more cost-effective on-site stabilization treatment, followed by disposal at a local landfill.

Case Study II: A Former Landfill

Investigation. Drums with hazardous waste were buried in a landfill, but no records were kept to document the nature of the hazardous waste or the number of drums. In 1985, during a Stage 1 site investigation, the RI contractor did not find any significant levels of contaminants at the site, and recommended additional investigation. In 1988, during a Stage 2 site investigation, another RI contractor conducted magnetic, electromagnetic and electrical resistivity surveys, a soil gas survey and placed 5 soil borings and one monitoring well at the site. Three soil boring samples contained total petroleum hydrocarbons (TPH) concentrations of up to 6700 mg/kg and various concentrations of benzene, toluene, ethylbenzene and xylenes (BTEX). Shallow buried drums were also uncovered.

In 1993, a third RI contractor conducted a Stage 3 site investigation, which included the placement of 5 borings to 50 feet bgs, 1 boring to 100 feet bgs, with a total of 12 soil samples collected at various depths. Eight surface soil samples were also collected. All samples were analyzed for volatile organic compounds (VOCs), pesticides, herbicides, polynuclear aromatic hydrocarbons (PAHs) and metals, and the data were validated.

The only contaminants found in surface soil samples were PCBs, with the highest concentration level measuring 54 mg/kg. The RI contractor unearthed five drums with hazardous waste that contained trichloroethane (TCA) and PCBs. Results of soil boring samples analyses did not show elevated target analyte concentrations and were consistent with the background concentrations at the site.

Based on the Stage 1, 2 and 3 SI reports, the RI contractor came to the following conclusions:

- The number of drums remaining in the subsurface was estimated at between 10 and 20. Later, after a second drum burial area was identified, this number increased to between 40 and 50.
- The size of the drum burial pit was predicted to be 40 feet wide, 40 feet long and 10 feet deep.
- The drums contained products with PCBs, and were the source of surface soil contamination.
- The volume of PCB-contaminated soil to be excavated was estimated at 300 cubic yards.

Remediation. A non-time-critical removal action was planned for the site. Site-specific cleanup criteria were set up for PCBs and TCA, and the EPA Region IX Preliminary Remediation Goals (PRGs) for industrial soil provided the framework of cleanup goals for an extensive list of target analytes.

DDT Concentrations	Number of samples collected at different depths			
	0.25 feet	2 feet	3 feet	4 feet
Below 1 mg/kg	14	11	4	4
Between 1 mg/kg and 10 mg/kg	12	4	None	None
Greater than 10 mg/kg	3	2	None	None
Maximum DDT concentrations at different depths, mg/kg	790	>60	0.2	0.73

Table 1. Summary of DDT screening.

In 1995, two years after the last SI at this site, a remediation contractor conducted a trenching drum removal action, during which *177 drums were removed.* Drum contents were composited and analyzed for disposal profiling. The highest PCB concentration found in the drum samples was 0.91 mg/kg. The only other target analytes detected at elevated concentrations were the BTEX compounds. Thirty cubic yards of excavated soil were not contaminated with PCBs.

In 1996, still another remediation contractor continued drum removal activities at the site. *A total of 469 decomposed, leaking drums were removed from a pit that measured 100 feet in length, 55 feet in width and up to 14 feet in depth.* The contents of the drums were composited and characterized for disposal profiling. The major components of the drum contents were diesel fuel and waste oil. One out of eight composite samples showed a concentration of PCB at 2.3 mg/kg, and TCA was detected in five samples at concentrations ranging from 1 mg/kg to 1300 mg/kg. In addition, the soil in some areas of the burial pit was grossly contaminated with diesel fuel and waste oil.

The last remediation contractor extensively characterized surface soil next to the drum pit by collecting 127 surface samples on a 20-foot-square grid and screening these for PCBs using immunoassay kits. *As delineated by the SI data, the characterized area should have covered 13,200 square feet east of the excavation pit. The actual extent of surface area contamination to the north, east and south of the pit, as determined by field screening, was 51,000 square feet.* The vertical extent of PCB contamination was limited to the upper two feet of the subsurface. Contaminated soil was selectively removed, and a total of 520 cubic yards of PCB-contaminated soil was disposed of at a Toxic Substances Control Act (TSCA)-permitted facility.

Why Did These Situations Occur?

In our opinion, these events took place because the RI contractor incorrectly focused on the accuracy and precision of the data, rather than data representativeness. For example, comparison of on-site screening results for the pesticide shop in Case Study I with the actual RI results showed a dramatic discrepancy in DDT concentrations. The RI contractor disputed the findings of the remediation contractor using the following arguments:

- The RI data were acquired according to the CLP protocols, followed by data validation, thus, they must be correct.
- The on-site laboratory screening results were too high. Since they were not obtained by the CLP protocol, it was claimed that they were likely to be incorrect.

To resolve the argument, homogenized split samples were analyzed by the on-site laboratory and by an off-site laboratory. The results obtained were comparable, and the concentrations of DDT were in the range of 300 mg/kg. The data sets obtained by the RI contractor and the remediation contractor were precise, accurate and legally defensible. However, due to inadequate sampling design, the data collected by the RI contractor were not representative of the site conditions. In our experience with DDT handling facilities, one can expect sporadic distribution of DDT at shallow depths in the subsurface. Surface soil contamination is affected by wind, rain and human activities, and often does not reflect the true site conditions. This project would have benefited if more samples had been collected and screened during the RI phase. *Placing emphasis on expensive analytical protocols and data validation rather than focusing on the sampling design and the project DQOs lead to misleading conclusions about the site conditions and in the selection of remediation options.*

It was apparent that the sampling plans for the landfill project in Case Study II were prepared by the geologists, because the RI/FS report was more detailed in its geology than its chemistry, and the focus of the investigations was on vertical rather than lateral site delineation. The three RI contractors, who were probably constrained by the project budgets, collected a very limited number of samples from the site. No field screening for soil was conducted; rather, the emphasis was on placement of expensive deep soil borings and data validation.

Discovery of shallowly buried drums during the Stage 2 investigation should have alerted the RI contractor to the fact that surface contamination from drum spillage and handling was a distinct possibility, and that more surface characterization would be beneficial. The presence of BTEX and TPH in the subsurface was an indicator that the drums most likely contained petroleum products. Nevertheless, the TPH analyses were not conducted during Stage 3 site investigation. Instead, the RI contractor used a more expensive PAHs analysis to delineate the site, without considering the fact that only trace levels of selected PAHs are present in refined petroleum products, such as diesel fuel and waste oil.

The three site investigations did not provide nearly enough information for estimating the magnitude of the cleanup effort. Inadequate numbers of samples and improper sampling design and analyses provided an unrepresentative picture of the true site conditions. That is why the number of buried drums and the extent of surface soil contamination with PCBs came as a major surprise during removal actions. The inability of the magnetic, electromagnetic and electrical resistivity surveys to distinguish between 10 and 500-600 steel drums buried at shallow depths makes one wonder whether these techniques were properly applied, or if results were misinterpreted.

Summary and Solutions

Remediation plans and projected costs of the remediation contractor are only as good as the conclusions of the latest RI/FS report at hand. Inadequate RI/FS work of the past resulted in lost time and money, and has caused loss of confidence in the accuracy of future RI/FS projects. The preoccupation of RI/FS contractors with data validation and a fear of screening and sample compositing to obtain more representative data are apparent. The prevalent problems, as we see them, are as follows:

- In the past, RI/FS work has been driven by the protocol, and not by the DQO process.
- Many RI/FS firms use chemists only for the preparation of the contract specific quality assurance project plans and data validation. Professional judgment of chemists has been neither valued nor solicited for data interpretation and preparation of sampling plans.
- Budgetary considerations often put constraints on the numbers of samples collected and types of analyses performed, and therefore, adversely affect the sampling design and sampling representativeness.
- The use of "low bidder" laboratories, procured without the project chemist's recommendation, has been a damaging practice and, in the past, it has produced a mountain of questionable data. The problem has been compounded by the management of subcontractor laboratories by non-chemist project personnel who are not knowledgeable in the areas of lab procedures and QA/QC protocols.

As an industry, we need to develop a better understanding of the DQO process and the intended use of the data. Perhaps then we can convince the regulatory community that if the tenets of the

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Horizon Speed-Vap 9000

Horizon Technology introduces the new Speed-Vap 9000 solvent evaporation system, designed specifically to perform EPA Method 1664 requirements. The system offers unattended evaporation of up to nine oil and grease samples simultaneously with a 25–50% reduction in evaporation time. The use of an adjustable vacuum system generates a gentle airflow over all samples. This safely collects all solvent vapors and allows for the use of an in-line solvent collection system. The safe benchtop design assures proper venting of all fumes and frees up vent hood space.

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INVESTIGATION

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old "CLP approach" are dropped, site investigations can be conducted in a more meaningful, productive and cost-effective manner. New tools for RI/FS are available today, such as numerous EPA-approved field screening methods for a wide range of contaminants, new and innovative techniques such as immunoassays, X-ray fluorescence and other improved field instruments, and performance-based analytical methods. Participation by experienced chemists in the development of the DQOs, in the preparation of the sampling and analysis plans, lab selection and oversight, and in the interpretation of data for the final report are all paramount ingredients for a successful RI/FS project.

Emma P. Popek, Ph.D., is field analytical services manager for OHM Remediation Services Corp. She is a Certified Quality Auditor (CQA) and a Certified Hazardous Materials Manager. Popek received her M.S. in chemistry from the University of St. Petersburg in Russia, and a Ph.D. equivalent from the USSR Academy of Sciences.

Garabet H. Kassakhian, Ph.D., was most recently quality assurance director of Tetra Tech, Inc., Pasadena, CA. He has more than 25 years of experience in federal environmental programs, environmental engineering, and the chemical, petrochemical and uranium mining industries. Kassakhian received his M.A. and Ph.D. in analytical chemistry from Harvard University.

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