



NJ Department of Environmental Protection
Division of Science and Research
CN 409, Trenton, NJ 08625-0409

RESEARCH PROJECT SUMMARY

October, 1995

Distribution of Mercury in Ground Water and Soils of the Kirkwood-Cohansey Aquifer System in the New Jersey Coastal Plain, Phase I: Development of Hypotheses as to Potential Sources of the Mercury

Research Project Summary Prepared by: Eileen A. Murphy, NJDEP

Principal Investigators

Julia L. Barringer, USGS
Cecelia L. MacLeod, USGS
Robert A. Gallagher, NJDEP

Eileen A. Murphy
Karl Muessig

Project Managers

Abstract

Data on mercury concentrations in water from potable wells in the southern part of New Jersey were collected from state and county records. These results were incorporated into a database and evaluated in order to discern the spatial and temporal distribution of mercury in ground water. Areas where at least one well sample yielded water containing mercury above the maximum contaminant level of 2 ug/L were classified as "contaminated sites". These sites were evaluated for similarities. Such parameters as land use history, proximity to industrial sites, cemeteries, hazardous and municipal landfills, household inputs such as exterior paint and septic leachate, and atmospheric deposition were investigated as potential sources of mercury to ground water. In order to verify the data that were previously collected and to gather additional information, a sampling effort for ground water and soil was conducted at some of the contaminated sites. Six hypotheses regarding to the origin of the mercury being found in ground water are offered, the first two of which have been dismissed as reasonable possibilities. They are: 1) sampling error; 2) pump materials; 3) household inputs; 4) point sources; 5) atmospheric deposition; and 6) land-applied mercurial pesticides. A second phase of this study is being conducted to further eliminate some of the hypotheses and to determine possible mechanisms for mobilizing mercury from soils to ground water.

INTRODUCTION

Mercury has been detected at levels

above those considered "safe" by the Environmental Protection Agency (EPA) in potable water samples in NJ. The current EPA maximum contaminant level (MCL) for mercury

in potable water is 2 µg/L. To date, water samples from 266 potable wells in NJ has been found to contain concentrations of mercury above this level. Preliminary investigations indicate that the contamination is limited to the unconfined portion of the Kirkwood-Cohansey (K/C) aquifer system which comprises most of the southern part of the State.

Some county health departments in the southern part of NJ have been collecting and analyzing water quality data since the 1970's. The information is generated, for the most part, as a result of routine monitoring of potable wells during real estate transfers. In some counties, the results of well-water testing are required to be reported to health departments. The problem of mercury contamination was first discovered in the 1980's when wells in a number of different residential areas in southern NJ were shown to have levels of mercury in the water at or above the EPA MCL of 2 µg/L. Some of these wells also contained other contaminants. As contaminated wells were discovered, health departments began to test neighboring wells. By 1994, samples from at least 266 potable wells in southern NJ were shown to yield water containing mercury levels above the MCL.

The NJ Department of Environmental Protection (NJDEP) conducted site-by-site evaluations in the impacted residential areas. The purpose of these evaluations is to delineate the extent of contamination, supply alternate water sources to affected residences, and to determine the potential source(s) of the contaminant. At some of the sites, point sources such as landfills or industrial sites were present; however, at most of the sites, no obvious source was evident, despite some wells showing mercury concentrations well above the MCL.

In 1992, the NJ Geological Survey (NJGS) of NJDEP analyzed the geochemical and lithologic factors affecting aqueous mercury concentrations in the K/C to determine if the mercury could be naturally-occurring (Dooley, 1992). Examination of the mineralogic characteristics of the sand, gravel and clay formations comprising the aquifer system indicated that the contamination could

not be natural. (It is interesting to note that mercury contamination in a granitic coastal environment in Maine is believed to be naturally occurring mercury in the rocks [Sidle, 1993]). In this same year, NJDEP worked with researchers at Skidaway Institute of Oceanography to investigate whether the mercury could be an artifact of sampling or laboratory contamination. The results of this study confirm that mercury was not introduced by sample handling nor was it the result of laboratory contamination or error (Murphy *et al.*, 1994; Windom & Smith, 1992). Multiple replicate and split samples analyzed by numerous laboratories using different analytical methods for mercury indicate that laboratory contamination is not the cause of the elevated mercury levels found in water samples.

In 1993, NJDEP commissioned the U.S. Geological Survey (USGS) to collect and evaluate existing ground water data on mercury in the K/C aquifer waters. Results from the USGS work are presented here.

OBJECTIVES

The overall goal of this first phase of a two-phase project was to examine the existing information on mercury monitoring in southern NJ in order to develop hypotheses regarding the source(s) of the contamination. Toward this end, the investigators outlined the following objectives:

- gather all NJDEP data on mercury concentrations in ground water;
- contact county health departments to retrieve existing records on mercury monitoring;
- compile data into one database and evaluate relationships among various factors;
- conduct water, soil and sediment sampling to verify and determine mercury levels to evaluate possible sources and to test some hypotheses;

- assess local hydrology and evaluate land-use histories at contaminated areas on a case-by-case basis for patterns or similar characteristics that may help to identify source(s) of the contamination; and
- devise scenarios that describe possible ways for mercury to enter the contaminated areas.

METHODS

In addition to retrieving mercury records from NJDEP, the investigators contacted representatives from Ocean, Burlington, Camden, Atlantic, Gloucester, Salem, and Cumberland Counties to obtain any information they had for mercury testing. Available data was incorporated into a master ASCII database file at USGS. USGS maintains records of its own well testing studies and included this information as well.

Database Generation and Site Evaluation:

Case-by-case evaluations of contaminated sites were performed using the Geographic Information System (GIS), USGS topographical maps, and aerial photographs (dating back to 1932). Possible sources of mercury within a three mile radius were considered. Ground water flow, where not available in published records, was estimated from topographic contours. The investigators examined the locations of the contaminated sites in relation to possible sources within three miles and upgradient of the sites. This distance reflects maximum possible migration of land-applied contaminants from approximately 50 years ago to the present. A total of 13 sites were evaluated in detail, which was the number of known contaminated sites at the time the study began. Currently, there are 32 sites in southern NJ where mercury concentrations exceed the MCL in well-water samples. Two additional sites have been identified where mercury concentrations are greater than 1 ug/L but less than the MCL of 2 ug/L.

The methods used to collect water, soil and sediment samples are standard

procedures and are described in detail in the full report (Barringer, et al. Draft Report).

Ground Water Sampling: Additional verification samples were collected from a number of wells; twenty-one from three contaminated sites, four from deep public supply wells within two miles of a contaminated site, two from wells in an undisturbed and pristine area, two from wells along a major roadway, and five from shallow wells. Samples were filtered before being collected in acid-soaked glass bottles. Equipment and field blanks indicated that no contamination occurred during sampling. Water samples were preserved and shipped on ice to the USGS National Water Quality Laboratory (NWQL) in Arvada, Colorado for analysis. EPA Method 7011 was used to analyze total mercury in the water samples.

Soils: Fifty-one soil samples were collected from 18 locations at six contaminated sites and one undisturbed site. Soils were collected using a trenching method and samples were separated by natural horizons or by changes in color, texture and grain size using clean stainless steel shovels and hand trowels. After collection, samples were stored in tightly-sealed glass jars and refrigerated until analyzed. Soil samples were analyzed by the Princeton Geology Department Laboratory (PGDL) using EPA Method 7012.

Quality Assurance/Control: For water and soil samples collected by the NJDEP, the counties and the USGS, equipment, field, trip and laboratory blanks were collected as part of the sampling design. Interlaboratory comparisons were performed to evaluate the accuracy of results. All QA/QC samples indicate that mercury was not being introduced through sample handling, analytical reagents or laboratory error.

RESULTS

Database Generation and Evaluation: Mercury data from 2,239 wells in 32 contaminated sites and two additional sites where mercury was detected but at levels below the MCL from

seven southern counties were collected from state and county records and incorporated into a database (Figure 1). Because Atlantic County is aggressive in its efforts to monitor wells, more sites have been identified in this county than in others. As the other counties have initiated or become more aggressive in their monitoring efforts, more sites have been discovered. Many wells at the sites were sampled more than once and the concentrations, in some cases, vary widely (e.g., mercury concentration from water in one well in Atlantic County ranged from 72 ug/L in early sampling events to 2.2 ug/L in the most recent sampling event). Of the 2,239 wells in the most recent sampling event, 266 contained mercury concentrations above the MCL of 2 ug/L with the highest concentration of 42 ug/L occurring at a site in Salem County. For consistency, values presented in the database reflect mercury concentrations for the most recent sampling event only. Table 1 shows the distribution of mercury concentrations in the database. Where more than one water sample was collected from a particular well, the mercury concentration from the most recent sampling event is included.

Table 1. Mercury distribution for wells according to county.

County	# wells	# wells > MCL	Median (ug/L)	Range (ug/L)
Atlantic	1,543	202	0.28	<0.01-34.5
Burlington	6	1	<0.01	<0.01-3.53
Camden	472	21	<0.50	<0.1-21.7
Cumberland	82	9	<1.00	<0.1-14
Gloucester	33	8	<0.20	<0.2-20.6
Ocean	51	19	1.10	<0.2-17
Salem	52	6	0.50	<0.2-42
Total	2,239	266	0.40	<0.01-42

Well depth information was available for 456 of the 2,239 wells (Table 2). Statistical analysis of mercury concentration with well depth on this set show no significant differences exist in median mercury concentrations for wells according to depth.

The statistical test used was the Mann-Whitney test for similarity of population medians for nonparametric data sets. The bulk of the wells sampled were 50-125 ft. which makes it difficult to evaluate mercury levels in the aquifer closer to the land surface and deeper than 125 ft. Additional information from wells screened less than 50 ft. and deeper than 125 ft. in affected areas is needed in order to better investigate this relationship.

In many instances, contamination of well water by volatile organic compounds occurred at the sites. Case-by-case evaluations show that the source of the mercury contamination may be different from the source of the volatile organic contamination.

Ground Water Sampling: Ground water sampling was performed to confirm earlier mercury testing and to include mercury data from shallow (< 50 ft.) and deep (> 125 ft.) wells. Repeat sampling was conducted at twenty-one residential wells from contaminated sites. Sampling also was conducted at: 1) shallow observation wells from two locations - a forested area and one of the contaminated sites; and 2) deep public supply and observation wells. Mercury was not detected in samples collected by the USGS from the shallow and deep wells. All USGS water samples were filtered through a 0.45 micron filter, whereas samples collected by state and county representatives were not filtered.

Mercury concentrations in filtered samples collected from wells which were sampled earlier by other laboratories show no discernible pattern; it is inconclusive whether filtering the water samples resulted in lower mercury concentrations. To further explore the effect of filtering, filtered and unfiltered water samples need to be collected during the same sampling trip.

Soil Sampling: Results from soil sampling indicate that mercury accumulates in undisturbed soil horizons dominated by organic matter or clay. Other researchers report that mercury is tightly bound to organic material and clays. Statistically significant correlations were found between mercury

concentration and organic matter content of the soil samples in disturbed areas. Because undisturbed areas had clearer horizon distinctions, patterns of mercury accumulation were clearly visible; higher concentrations of mercury were found in the organic- or clay-rich horizons. Mercury concentrations in soils from undisturbed areas taken to a depth of 2 ft. ranged from 11 to 146 ug/kg (median 97.6 ug/kg). This pattern of mercury accumulation in forest soils has been described by other researchers. In particular, Grigal et al. (1994) report mean mercury concentrations of 143 ug/kg in the organic layer of forest soils and 11-36 ug/kg in deeper layers. Mean mercury concentrations in the organic layer of soils in former agricultural areas which have become forested are reported as 76 ug/kg and in deeper layers, 8-14 ug/kg (Grigal et al., 1994).

Table 2. Mercury distribution for wells according to well depth.

Depth (ft.)	# wells	# wells > MCL	Median (ug/L)	Range (ug/L)
0-25	1	0	1.04	1.04
26-50	20	1	0.215	<0.1-5.2
51-100	291	46	0.270	<0.01-22.5
101-150	138	23	0.395	<0.1-18.64
151-200	6	1	0.190	<0.1-9.51
>200	0	-	-	-
Total	456	71	0.30	<0.01-22.5

Soils from residential areas, however, where organic matter content was often low and soil horizons were blended or obscured, contained less mercury than the more organic-rich soils. Mercury concentrations in soils taken to a depth of 1.5 ft. from residential areas ranged from 10 to 102 ug/kg (median 17.6 ug/Kg excluding values from samples collected at a former thermometer factory where mercury levels as high as 259 ug/kg were detected).

Case-by-Case Evaluations: Using GIS, areal photographs and NJDEP records, the researchers investigated the contaminated

sites for similarities and, in particular, thoroughly examined 13 of the sites (at the time of this study, only 13 sites had been identified). Some common characteristics at the sites were:

- the occurrence of volatile organic chemicals, particularly chloroform, benzene and xylenes;
- agricultural land use at some point at or upgradient of the sites between the years 1940-1993;
- residential development with construction occurring after 1950;
- location of sites on uplands on or near local topographic divides;
- proximity of sites to at least one potential point source (within three miles though not always down gradient); and
- sites subject to global and regional atmospheric deposition.

Hypotheses Generation: The end product of this research was the development of hypotheses regarding potential sources of the mercury contamination. Six hypotheses are offered, the first two of which have been dismissed as possibilities. The remaining four are currently being pursued in the Phase Two study.

1. The mercury is an artifact of sampling or is a result of laboratory error. Confirmatory sampling and other research in the area show that the mercury contamination in ground water is a real phenomenon and not the result of sample contamination or lab error.
2. The mercury is from well construction or well pump materials. Analysis of data where information on well construction and well pump manufacture were available indicate that the mercury is not coming from any well material.
3. The mercury reached ground water from household sources such as septic tanks, well disinfection or exterior mercury-based paint.
4. The mercury leached from point sources such as municipal or hazardous waste landfills, military installations, industrial or

commercial sites, cemeteries, or spills from mercury-based pesticides.

5. The mercury is a result of atmospheric deposition.

6. The mercury leached from surface application of mercury-based pesticides.

Phase Two of the study involves the investigation of the hypotheses developed during Phase One. It is likely that the mercury in ground water in southern NJ is the result of multiple sources with certain sources being more important than others in particular areas.

RECOMMENDATIONS

The State has been evaluating mercury contamination sites since the first cases were discovered in the 1980's. As information becomes available, it is apparent that mercury contamination is widespread in the NJ Coastal Plain. Given the nature of the contamination, it is important to sample ground water throughout the unconfined portion of the aquifer system. Future research efforts should include monitoring in counties where information is lacking and should include both shallow and deep wells. NJDEP therefore recommends that all private wells tapping the unconfined portion of the Coastal Plain be monitored for mercury. Since the State has no legal authority to sample private wells, it is recommended that private homeowners served by wells have their well water analyzed. Water testing is already required locally for real estate transactions in some counties although routine monitoring is not required. The State advises homeowners to contact their local health departments or the NJDEP to find out more about how to have their water tested for mercury (and other contaminants).

Information generated by sampling should be reported to the health departments and/or NJDEP even in instances where mercury is not detected.

IMPACTS TO THE STATE

Homes whose well water was found to have levels of mercury routinely above the MCL have been given point-of-entry treatment units (POETs) to filter out the mercury or have been connected to community water supplies. The NJ Spill Compensation Fund has funded these remediation efforts because the mercury is believed to be anthropogenically derived. The Safe Drinking Water Research Program (A-280) has funded the research studies investigating the potential sources of the mercury and other drinking water related studies in the area.

REFERENCES

Barringer, J.L., C.L. MacLeod & R.A. Gallagher (draft) Distribution of mercury in ground water, soils and sediments of the Kirkwood-Cohansey aquifer system in the New Jersey Coastal Plain, Phase I: Development of hypotheses as to potential sources of the mercury, Draft Final Report submitted to NJDEP for contract #34924, Trenton, NJ..

Dooley, J.H. (1992) Natural sources of mercury in the Kirkwood-Cohansey aquifer system of the NJ Coastal Plain, NJGS Report 27, Trenton, NJ.

Grigal, D.F., E.A. Nater & P.S. Homann (1994) Spatial distribution patterns of mercury in an East-Central Minnesota landscape, In: Mercury Pollution: Integration and Synthesis, Eds. C.J. Watras and J.W. Huckabee, Lewis Publishers, Boca Raton, FL.

Murphy, E.A., J. Dooley, H.L. Windom & R.G. Smith Jr. (1994) Mercury species in potable ground water in southern New Jersey, *WATER, AIR AND SOIL POLLUTION* **78**: 61-72.

Sidle, W.C. (1993) Naturally occurring mercury contamination in a pristine environment? *ENVIRONMENTAL GEOLOGY* **21**: 42-50.

Windom, H.L. & R.G. Smith Jr., (1992) Analysis of mercury species in ground water using inductively coupled plasma - mass spectrometry and gas chromatography, NJDEP

ADDITIONAL INFORMATION

Julia Barringer is a Senior Hydrogeologist with the US Geological Survey, Water Resources Division. At the time of this project, Cecelia MacLeod was a Hydrologist with the group.

Robert Gallagher is a Hazardous Sites Mitigation Specialist at NJDEP, Bureau of Site Management in the Division of Publicly Funded Site Remediation. Eileen Murphy is a research scientist with the NJDEP, Division of Science and Research. Karl Muessig is a Supervising Geologist with NJDEP, NJ Geological Survey.

For a copy of the final report or for additional copies of this summary, contact the Division of Science and Research at (609) 984-6070. Reference #9500 .

Figure 1. Locations of sites of mercury-contaminated ground water and areal extent of the Kirkwood-Cohansey aquifer system.