United States
Environmental Protection
Agency

High Radium Levels in Anne Arundel County Drinking Water Corrected

Partnerships and collaboration made the difference

Background

In the late 1980's, high cancer death rates in Anne Arundel County, Maryland were made a health priority. Tobacco and other lifestyle issues were targeted but concerns in the community resulted in an Advisory Task Force to study health and environmental factors to see if there were other factors involved.

1995 Task Force

Charge:

1. Develop recommendations for control and prevention of cancer;
2. Collect and maintain data about health behaviors and environmental risks leading to high cancer rates; and
3. Advise on ways to reduce cancer risk.

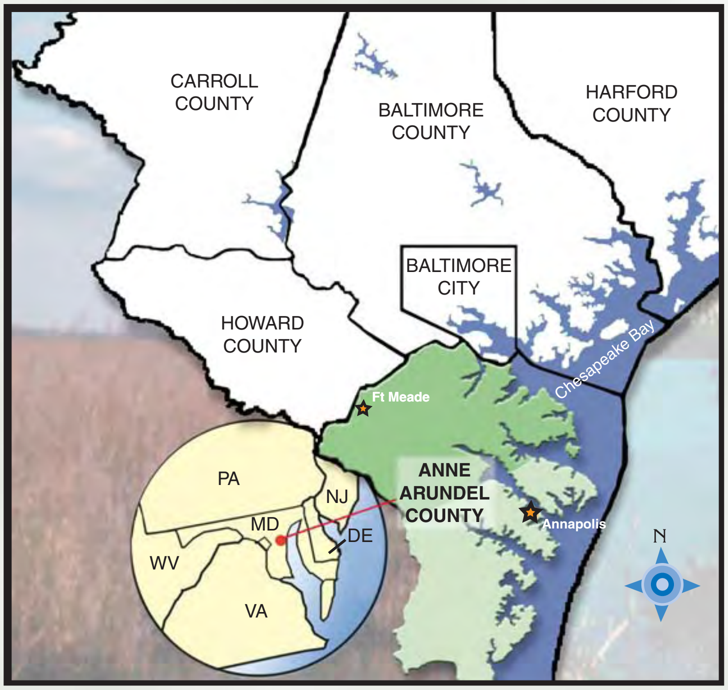
The Task Force included concerned citizens, physicians, public health officers, scientists, engineers, lawyers, and EPA officials. It published its findings and recommendations in 1996.

Conclusion:

- Tobacco use, lack of medical screening, and lack of proper diet and exercise were major factors in cancer rates.
- Not enough was known about air and water pollutants to determine their role as contributing factors.

Recommendation:

The task force recommended that the Anne Arundel County Department of Health (AADOH) investigate groundwater supplies as little data was available about carcinogens in private well water.



Source: Baltimore Council of Governments, 2003

Figure 1. The dark green portion of Anne Arundel County represents the testing area for gross alpha and radium 226/228.

Pilot Study

As a result of the Task Force's recommendation, AADOH and Anne Arundel County Department of Public Works (AADPW), the Maryland Geological Survey (MGS), and the U.S. Geological Survey (USGS) conducted a groundwater quality pilot study in 1997. The pilot study included areas where groundwater was vulnerable to carcinogens, including industrial and commercial sites, areas with naturally occurring radionuclides like radon, and agricultural areas where pesticides were a potential contaminant. Forty-seven domestic wells were tested for 43 contaminants: inorganic constituents including iron and nitrate, radionuclides (uranium and radium), volatile organic compounds (evaporating chemicals such as benzene), and pesticides.

Health Risk of Radium Consumption

EPA classifies radium-226 and radium-228 as human carcinogens (cancer-causing). They are in a group of carcinogens that have the most severe effect on humans and show a causal relationship to human bone cancer. EPA's standard for the maximum contaminant level (MCL) for combined radium-226 and radium-228 in drinking water is 5 picocuries per liter (pCi/L) – a measure of radioactivity.

Radium enters the body when it is swallowed. If it is ingested in water or food, approximately 80% is voided naturally; the other 20% enters the bloodstream and organs and migrates to the bone. Radium-226, once attached to bone, remains in the body for a person's entire life. Adverse health effects from high levels of exposure include bone and skull cancers, anemia, cataracts, fractured teeth, bone tissue breakdown, and death. The additional lifetime risk of cancer from consuming drinking water with 5 pCi/L of radium is estimated at about 1 in 10,000. As radium concentration increases, so does the cancer risk.

Pilot Study Results

- For the majority of wells in the pilot study, no contaminants exceeded the Safe Drinking Water Act's maximum contaminant level (MCL).
- Arsenic above the MCL was detected in several samples.
- High concentration of radium was verified in three geological formations: Magothy, Patapsco, and Patuxent aquifers (Figure 2).
- **Radium-226 and radium-228 concentrations were detected at rates above the MCL of 5.0 picocuries per liter (pCi/L)**. Fifteen water samples in the Magothy and Patapsco Formations (northern and central county) had radium concentrations that exceeded federal drinking water standards.

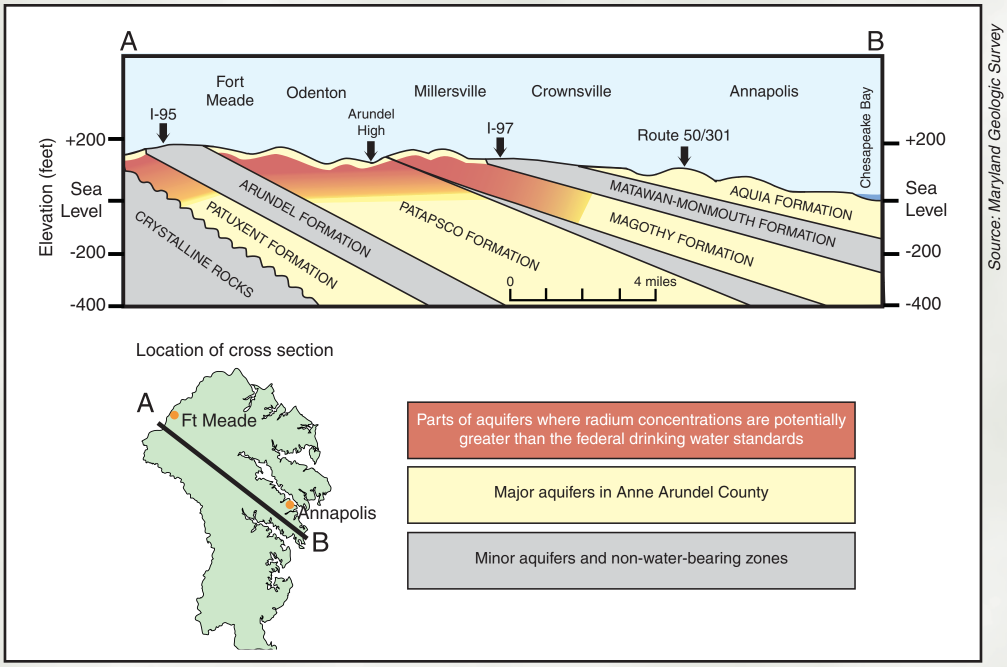


Figure 2. Geological formations in northern Anne Arundel County.

Radium is naturally occurring; radium-contaminated groundwater is the result of a natural hydrogeological process and possibly compounded by human factors. Research has yet to determine how radium contaminates groundwater; but, there is evidence from this study that when an unconfined aquifer is acidic (pH levels less than 6), radium is released from the aquifer materials into the groundwater in Anne Arundel County. Radium is also released when the ground- water contains high amounts of dissolved solids, particularly sodium and chloride, which indicates that human activity may contribute to the problem. Figure 2 (above) shows the locations in the aquifers where high levels of radium occur in the groundwater, which range in depth from the surface to about 100 feet below sea level. The highest level of radium detected in the study was 66 pCi/L – over thirteen times the acceptable level.

Follow-Up

Although surveillance data indicated no increased level of bone cancer in the affected area, the County had concerns for the potential for increased health risks. County officials received the results of the pilot study and conferred with the Maryland Department of the Environment (MDE). Because two of the aquifers (Patapsco and Magothy) having high radium concentrations in the Anne Arundel County study are used throughout the upper Chesapeake Bay area, MDE was concerned that the problem may not be limited to Anne Arundel County. To establish the full extent of contamination, MDE recommended expanding the study into other areas in Maryland where the aquifers are used for drinking water. The study expansion received financial support from EPA's Mid-Atlantic regional office. The agencies worked together to survey and test the groundwater in this area during 1998; 203 wells were sampled. High radioactivity in groundwater was confirmed in northern and central Anne Arundel County, but generally not found elsewhere. This suggested that the radium was localized within the shallow groundwater of these aquifers.

About 49% of the 203 wells tested exceeded the MCL. Six of the wells in the coastal plain that exceeded the MCL for gross alpha particles were not in Anne Arundel County. By early 2000, AADOH had acquired significant evidence that the aquifers that supply drinking water to approximately 20,000 residents in northern and central Anne Arundel County were contaminated. Most homeowners were not exposed to high radium-levels since most radium-contaminated wells were equipped with systems for iron removal, which effectively reduces radium exposure to negligible levels.

The data revealed various patterns of high radium concentrations:

- **Radioactivity was highest in the shallow unconfined parts of the Coastal Plain aquifers.**
- **Radioactivity tended to be lower in deeper, confined aquifers;** in nearly all sampled wells deeper than 300 feet, radium concentrations were below the MCL.
- **Radioactivity tended to increase as the pH of the groundwater decreased.**
- **Radium increased in direct proportion to increases in sodium and chloride.**
- **Radium-224, which has a half-life of 3.64 days, appears to be the dominant radium isotope.**

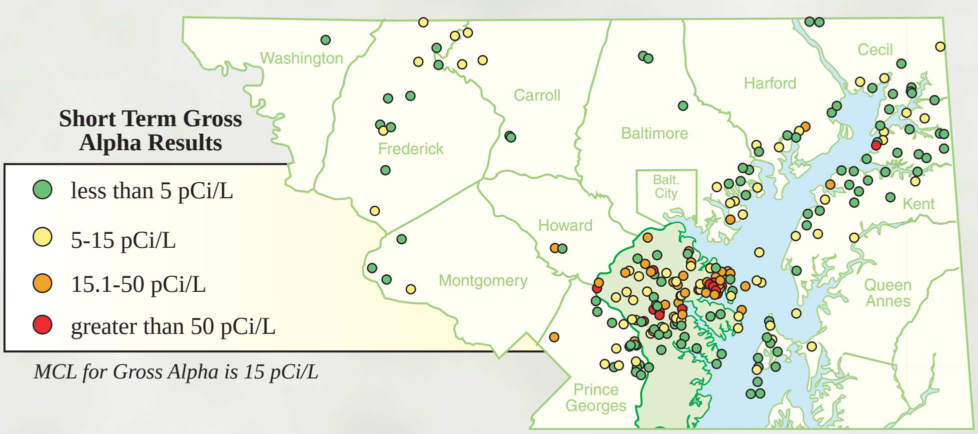


Figure 3. Results of gross-alpha testing from wells in the Patapsco, Magothy, and selected Piedmont aquifers.

88
Ra
226.0254

Radium (Ra) is the heaviest alkaline earth metallic element; it occurs naturally and is extremely radioactive. Radium is formed by uranium and thorium decay. Three isotopes of radium were detected in Anne Arundel County. Radium-224 is not regulated in public water supplies because of its short half-life (3.64 days); radium-226 has a half-life of 1,622 years and emits alpha particles. ***Gross alpha particle activity (GAPA)*** *is an indicator of the amount of alpha-emitting radionuclides, including radium-224 and radium-226.*

Radium-228 has a half-life of 5.75 years and emits beta particles. ***Gross beta-particle activity (GBPA)*** *is an indicator of the amount of beta-emitting radionuclides, including radium-228.*

Radium isotopes are found in soil, rocks, plants, food, and groundwater.

Water samples were analyzed for both short and long-term GAPA and GBPA.

Short-term measurements were made within three days of sample collection, while long-term measurements were made on the same sample approximately 30 days after collection. If the long-term GAPA is much less than the short-term GAPA, the decrease is due to the rapid decay of radium-224 or other alpha-emitting radionuclides having short half-lives.

Management Implications

County health officials took steps to protect the local school system from radium in drinking water supplies. Elevated radium levels were detected in the drinking well water in four County schools. As an effective interim solution, bottled water was provided. All households of enrolled students were notified, water treatment systems were installed and deeper wells were drilled (based on evidence from the study) to ensure safe drinking water for all of the schools.

The County communicated the problem and its solutions to the public. Effective communication was critical. The County launched a public information campaign to define the problem and explain the options for safe mitigation.

- The results of the scientific studies were conveyed to the public. Residents whose wells were sampled were alerted by mail. The County issued press releases about the findings after the presence of radium was confirmed. Then, the new regulations for well drilling went into effect.

- Public outreach was conducted while radium assessment continued. A radium fact sheet was produced and continually updated about radium, its effects, and options for mitigation.

Photo courtesy of USGS

Figure 4. Measurements of water levels in groundwater wells are needed to define the direction of groundwater flow.

- Two open houses and 8 community meetings were held at various schools to bring government officials and the public together. The meetings were advertised on radio, television, and in the newspaper. Government and private experts staffed stations to respond to residents' concerns. By collaborating with other state and federal agencies, AADOH was able to provide residents with detailed and factual information. This public forum had several advantages:

  - Residents were able to obtain information specific to their concerns. Tables were set up for residents to receive radium information from EPA, AADOH, the Board of Education, doctors, and scientists.

  - It provided a less formal environment that was welcoming and not intimidating. Residents could walk around the meeting place at their own pace to learn about their specific concerns.

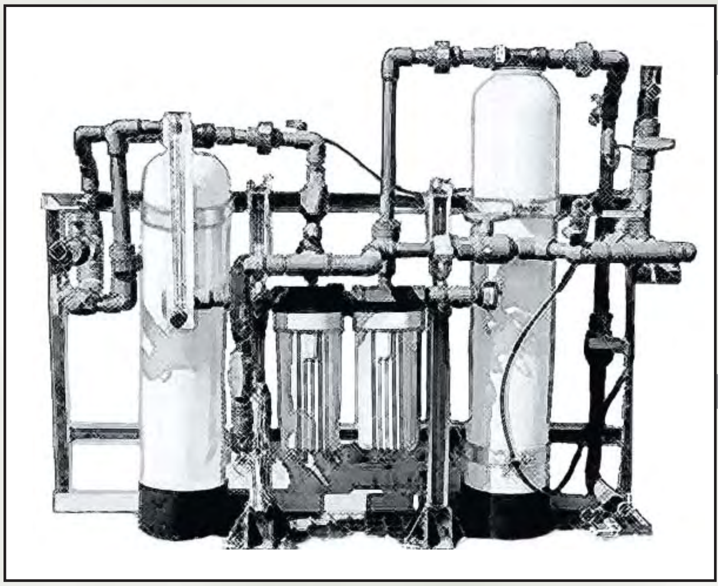
  - The open houses provided residents who sought information an ample opportunity to ask questions. This avoided the traditional public meeting format, where it is easy for one or two people's opinions to dominate and there are few one-on-one interactions.

A mass mailing to about 20,000 residents alerted them of the detection of radium and ways to mitigate its effects. The County continues to offer information to new homeowners about radium mitigation. It requires all new wells to be tested for radioactivity and radium.

Solution

A short-term solution was developed to provide the affected area with safe drinking water. MDE played a key role in developing a course of action. In 1998, MDE issued a directive mandating new standards for new and replacement wells drilled in northern Anne Arundel County. Wells constructed after June 1, 1998 were required to be tested for gross alpha particles as a condition of the Certificate of Potability (COP). Where results were found above the MCL, an effective treatment system was required. In addition, the property owner was required to sign an agreement certifying that he or she is aware of the test results and that the potability of the water supply is dependent upon proper maintenance of the treatment system. The signed agreement was recorded against the deeds of the affected properties to ensure future buyers were aware of the maintenance responsibilities.

AADOH and MDE then worked together to provide treatment options for homeowners who elected not to replace wells immediately. Once the well water was found contaminated, the homeowner had a choice of one of two recommended water treatment systems — ion exchange or reverse osmosis.

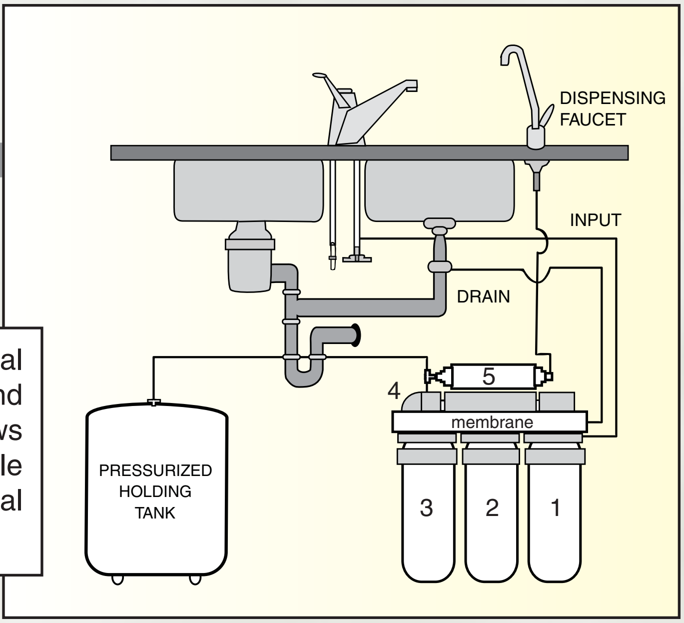


ION EXCHANGE SYSTEM

This is a water softening system capable of treating an entire household's water supply. It is typically used to decrease iron, calcium, and magnesium deposits. An ion exchange system tends to produce excess sodium, so it may not be appropriate for persons with diet restrictions.

REVERSE OSMOSIS SYSTEM

This is a point-of-use system where individual faucets throughout the house are targeted and filtered. It is a mechanical process that allows some molecules to pass through a filter while leaving others in the unit and is an economical approach to providing safe drinking water.



Long-term solution: AADOH, MGS, and MDE also developed a database of radium samples. Nearly 2,000 samples were analyzed and catalogued. The County and the State, with technical assistance from EPA's Mid-Atlantic Integrated Assessment (MAIA) program, developed a computerized three-dimensional GIS (geographic information system) operating model. Using radium samples as a data source, the operating model indicates how deep a well must be to avoid high radium levels. The County utilizes the operating model to issue permits for the construction of new and replacement wells.

Ninety-five percent of the new wells drilled to the specified depth have radium concentrations below the MCL (compared to 33% of the wells drilled prior to minimum depth requirements).

Photo courtesy of AADOH

Figure 5. Drilling new, deeper residential well.

Photo courtesy of USGS

Figure 6. Technician in a vehicle specially equipped for the handling of water quality samples.

Photo courtesy of USGS

Figure 7. Field analysis.

Costs

Funding for various activities was necessary. First, there were studies to define the extent of the problem (Figure 8). Second, there was a collaborative effort among scientists, public health officers, and elected officials to correct the problem. Full-time staff were assigned from MDE Water Management Administration, USGS Water Resources Program, MGS Hydrogeology Division, and AADOH Division of Community and Environmental Health. EPA's MAIA program developed a 3-D GIS computer model, based on MGS's contours and 3-D map to predict the occurrence and location of the radium, and trained the State and County to use the model.

Other costs were associated with testing individual private wells for radioactivity. A short-term gross alpha test was used as a screening test for high radium levels. The gross alpha-particle test costs $64. If the results are within the acceptable range, no further testing is necessary. If the initial testing results are between 5 and 15 pCi/L, specific testing is necessary for radium-226 and radium-228. A test for combined levels of radium-226 and radium-228 costs $158. Homeowners with existing private wells typically pay these testing expenses. MDE and AADOH contributed to the purchase of new laboratory equipment (a low-level automated Alpha-Beta counter) to allow state testing for short-term gross alpha particles.

All mitigation options provided safe, cost-effective drinking water. These options were far less expensive than extending public water to all affected areas. Anne Arundel County estimated that it would cost nearly $30,000 per household and, even spread over 30 years, would be prohibitive for many households. Therefore, methods of mitigation at the household level were deemed more appropriate by the county and state.

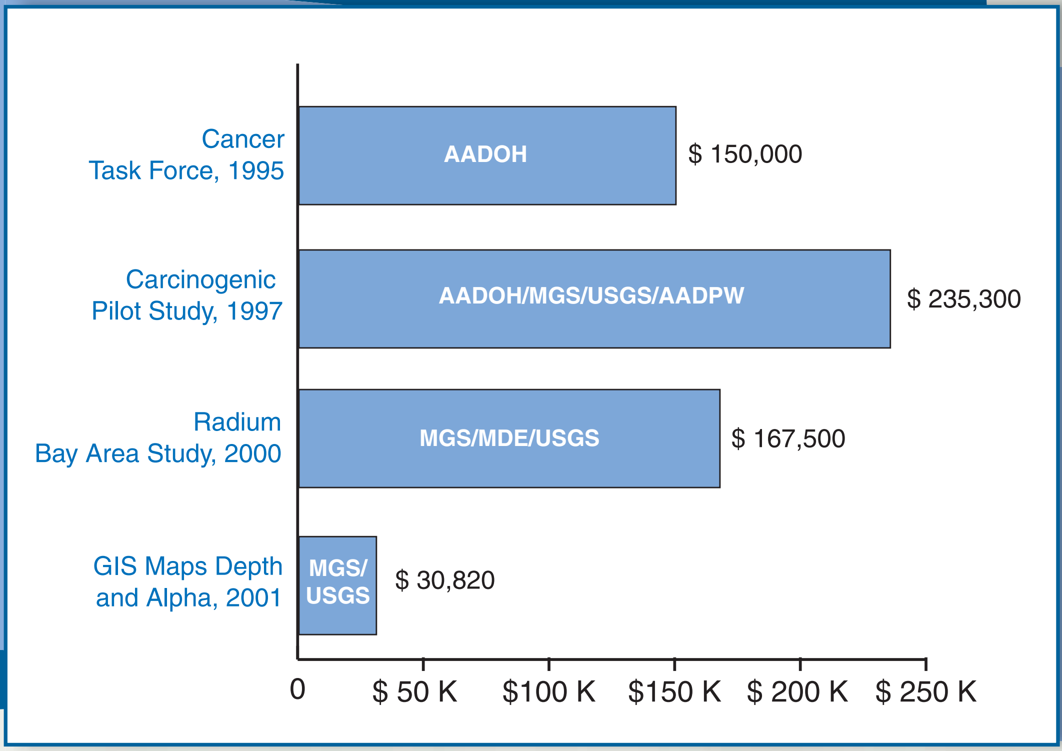


Figure 8. Radium assessment and mitigation study costs.

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Initiatives, Accomplishments & Results

- Proactive environmental management in the County resulted in the creation of the Anne Arundel County Advisory Cancer Task Force that led to the detection of radium in the groundwater.
- Full scientific assessment was crucial. Two studies determined the extent and distribution of radium concentrations to provide the health risk assessment.
- Intergovernmental cooperation was a key to success. Multiple agencies were involved in all stages of assessment, mitigation, and public outreach:
  - The County and State conducted comprehensive health risk assessments of the danger of radium consumption;
  - The County and State worked together to determine and communicate the degree of contamination;
  - EPA's MAIA team assisted with GIS expertise to provide a mapping tool to help understand and manage the radium contamination.
- Maintaining open channels of communication was integral to sustaining the trust of the County's citizens:
  - Early and full disclosure helped to establish trust and develop rapport with the residents;
  - Open-house meetings were a valuable mechanism to convey information and interact with the community;
  - Residents' perception of risk needed to be considered;
  - Fear, emotion, or lack of interest was not allowed to dictate mitigation strategies.
- A thorough knowledge of the nature of the problem provided effective mitigation options.
- The solution had to balance risk and mitigation options and consider various factors.
- Implementation of public policies and environmental management practices provided for effective prevention of a public health problem.
- Ninety-five percent of the new wells drilled to the specified depth have radium concentrations below the MCL.

MAIA Best Management Practices Case Studies Course

Organizations throughout the Mid-Atlantic region have developed and implemented unique approaches to respond to environmental problems and concerns. The Mid-Atlantic Integrated Assessment (MAIA) has also conducted considerable research in the region, much of which has been used by environmental managers to meet their responsibilities.

MAIA and UMBC initiated a graduate-level research seminar where students document these success stories so that other managers and organizations can also use these approaches and research.