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CASE HISTORY OF A SMALL WATER SYSTEM ADDRESSING RADIOLOGICAL CONTAMINATION

Author: Daniel B. Horne, P.E.
Virginia Department of Health
Office of Drinking Water
830 Southampton Avenue, # 2058
Norfolk, VA 23510

ABSTRACT

On 7 Dec 2000, the U. S. Environmental Protection Agency published a revised standard for radiological contaminants in drinking water. This revised standard included a new standard for uranium. Systems which previously did not consider uranium to be a problem now have to address the uranium content of their water.

This paper will present a case history of a privately-owned water system, serving a small rural community, which found high levels of uranium in the water supply (groundwater). The project team includes the waterworks owner, the equipment manufacturer, the regulatory agency, and the local government (even though they don't own the water system). The discussion will address the preliminary testing results, the technology applied, the full-scale testing of that technology, the acceptance by the state regulatory agency, and how the project team worked together to develop a successful project, leading to long-term operation.

The paper will also discuss how the water system has responded to finding that the water also contains levels of radon in excess of the standard proposed by EPA in a 1999 draft rule that has not yet been finalized.

KEYWORDS

Uranium, radon, radionuclides, small systems, ion exchange

INTRODUCTION

Fox Run Water Company (Fox Run) owns and operates a small water system which serves the Chesdin Manor and River Road Farms subdivisions in Dinwiddie County. The system, known as the Chesdin Manor system, was originally built in 1977 and expanded in 1980, and consists of two well stations, each with a single well, bulk storage, booster pumps, and a hydropneumatic pressure tank, to serve a design service area of 147 connections. Because of a slow build-out, the system has been operated with each well delivering water through a pressure tank to the distribution system, which was divided into two separate service areas, with a total service population of 118 homes.

The system consistently met all water quality standards established under the Safe Drinking Water Act. Monitoring performed in response to the radionuclides rule (beginning in 1980) revealed the presence of uranium in the water, but there was no standard for uranium at that time. Based on the application of the radionuclides rule, the Chesdin Manor system was deemed to be in compliance with the rule.

Occurrence and Health Effects

Uranium is a heavy metal that occurs naturally in the environment. It undergoes radioactive decay, creating radium as the immediate daughter product and emitting alpha particles in the process. Certain rock types have naturally occurring trace amounts of radionuclides, including uranium, which may accumulate in drinking water sources, typically groundwater, at levels of concern. Drinking water exposure may occur through accidental releases of man-made radioactive substances or through improper disposal practices, but this is extremely rare. The exposure risk from uranium comes from the ingestion pathway. The primary health risk from uranium is due to a chronic chemical toxicity to the kidneys, although some persons who consume water containing high levels of alpha activity for long periods of time may have an increased risk of stomach cancer.

Radon (Rn-222) is a gas that is eventually formed by the radioactive decay of the ultimate parent element, uranium-238. Radon undergoes further radioactive decay, emitting alpha particles in the process. The gas is odorless, tasteless, and colorless, and has a very high activity in relation to it's concentration in water. Radon is a carcinogen, with human exposure due to both inhalation and ingestion. Radon moves readily through the ground, and concentrates inside structures that are not adequately ventilated. Radon dissolved in water will transfer from the aqueous phase into the air very rapidly during normal water use such as showering, toilet flushing, etc. The most important exposure route is via inhalation. The health risk from inhaled radon is due to the radon aerosols that collect inside buildings, eventually depositing in the lungs, where they release their radiation, significantly increasing the risk of lung cancer. Consumption of drinking water containing radon presents a smaller risk of internal organ cancer, primarily stomach cancer.

In Virginia, there are several areas of the state, primarily in the Piedmont region, where the geological makeup includes rocks that contain levels of natural uranium high enough to yield waters with uranium higher than the standard. There are many areas in the state where the geology includes rocks that release radon in sufficient quantities that the indoor air in some homes exceeds suggested guidelines for radon, to the point where remediation is necessary.

Regulatory Background

On 7 Dec 2000, the U. S. Environmental Protection Agency (EPA) published a revised rule for radionuclides (radiological contaminants) in drinking water. This revised rule included a standard for uranium, which had not previously been regulated. In fact, under the original radionuclides rule, if the gross alpha activity exceeded the Maximum Contaminant Level (MCL), any alpha activity due to uranium was subtracted from the total gross alpha to obtain an "adjusted gross alpha", which was then compared to the MCL. EPA set the new MCL for uranium at 30 µg/L. Water systems were to begin monitoring for uranium beginning 8 Dec 2003, unless the State allowed the use of grandfathered data. Initial monitoring consists of samples collected for four consecutive quarters, at the entry point to the distribution system. The average of the four quarters of monitoring is compared to the MCL. Systems are required to complete their initial monitoring by 31 Dec 2007.

Because the original radionuclides rule had required speciation of the gross alpha emitters, the Virginia Department of Health (VDH) was aware of systems, such as Chesdin Manor, that had previously shown the presence of uranium in their water. VDH determined that these systems would need to conduct their monitoring at the very beginning of the monitoring period to confirm the level of uranium present and, if necessary, move to achieve compliance with the new MCL well in advance of the 2007 deadline.

On 2 Nov 1999, the U. S. Environmental Protection Agency published a proposed rule for radon in drinking water. The proposed rule contained both a proposed MCL of 300 picoCuries per liter (pCi/L) and an Alternative Maximum Contaminant Level (AMCL) of 4,000 pCi/L, to be allowed if the state regulatory agency implemented a Multi-Media Mitigation (MMM) program, for the mitigation of high levels of radon in indoor air. If the State did not elect to implement an MMM, individual water systems could choose to establish such a program on the local level and still be allowed to use the AMCL. The proposed rule was very controversial, and EPA received large numbers of comments. EPA has been reviewing the comments, and deciding how and if to modify the proposed rule since. EPA's most recent schedule calls for the final rule to be promulgated by the end of 2006. In the absence of an established rule for radon, there is no requirement for monitoring radon in drinking water.

It is important to note that the major risk from radon is due to inhalation of the gas. There is no mandatory program for monitoring indoor air quality, nor is there any enforceable standard for indoor air radon. EPA has suggested that buildings that show measurements of 4.0 pCi/L of radon in the indoor air need to be remediated. By way of comparison, the conversion factor for radon in water to radon in air is that 10,000 pCi/L in water will yield 1.0 pCi/L in air.

PROJECT DEVELOPMENT

As noted in the introduction, monitoring of the Chesdin Manor water system conducted during the developmental stage and during the early stages of system operation revealed that the water contained uranium. Monitoring was performed by Fox Run in accordance with the rules in effect at the time, such that some tests were conducted in the distribution system and some at the entry point. Further, until the revised radionuclides rule was published in 2000, the analyses were of activity (yielding a result in pCi/L) rather than of concentration (results in µg/L). Table 1 shows the results of the monitoring from Chesdin Manor over the years. It should be pointed out that the gross alpha results (and uranium results) have tended to increase over time.

Table 1 – Historical Radiological Results

Year	Location[1]	Gross Alpha[2]	Uranium[2]	Gross Alpha[2] (EP1)	Uranium[2] (EP1)	Gross Alpha[2] (EP2)
1980	Well	8.9 – 13.0	NA			
1982	Distribution	20.0 – 27.6	21.1 – 26.3			
1988	Distribution	43.2				
1992	Entry Points			39.8	42.4	1.0
1996	Entry Points			31.6	34.0	1.7
2000	Entry Points			72.5	77.1	6.4

[1] Required monitoring point moved from well development to distribution system to entry point
[2] Results reported as pCi/L

Because the radionuclides rule did not originally set a standard for uranium, but only for gross alpha (or where the gross alpha activity could be shown to come from uranium, adjusted gross alpha), the Chesdin Manor system was deemed to be in compliance with the radionuclides standard.

That changed with the promulgation of the revised radionuclides rule, on 7 Dec 2000. The new rule established an MCL for uranium of 30 µg/L. VDH analyzed the previous measurements at Chesdin Manor by converting them from an activity to a concentration. The analysis indicated that the uranium would range from a low of 31.5 µg/L to a high of 115 µg/L, which would exceed the new standard. VDH determined that the system would need to be monitored early in the monitoring period, to confirm any possible exceedance of the MCL, and move towards remediation leading to compliance. Non-compliance samples were collected in June 2004 and analyzed, which confirmed that the water from both wells, and at the customers taps, exceeded the new MCL.

As part of the early compliance effort, the consumers were notified by the Dinwiddie County Health Department that the water contained levels of uranium in excess of the MCL. The concern generated by this notification led to the project being fast-tracked, in order to alleviate the concerns of the consumers. Alternate water supplies were made available to the residents, including a bulk storage tank with service taps at one of the two well stations and fill taps made available by the County at the Dinwiddie County Water Authority office. Many of the residents did not avail themselves of the alternate supplies. A complicating factor was that one resident of the system had been tested due to health concerns at his job, and found to have elevated levels of uranium in his body. This led to much concern about the safety of the water for all concerned.

After discussions with VDH, Fox Run began researching possible alternative treatment strategies. The radionuclides rule identified several technologies for uranium removal as acceptable compliance technologies for small systems, with five technologies [centralized ion exchange, point of use (either by ion exchange or reverse osmosis), centralized activated alumina, and enhanced coagulation/filtration] classified as Best Available Technology for small systems (in the population category that included Chesdin Manor). Fox Run quickly determined that most available treatment options that had a demonstrated track record were for systems of much larger size. Selecting a treatment option was complicated by the difficulty of dealing with any residual stream. There was no central sewer to which a waste could be discharged, and a point-source discharge was not possible, as the receiving body of water (Lake Chesdin) serves as the terminal reservoir for the Appomattox River Water Authority, which operates a large surface water plant serving the nearby metropolitan region.

Fox Run did eventually find Water Remediation Technology LLC (WRT), a supplier of a centralized ion exchange system that could provide a treatment unit of a size that was appropriate for the Chesdin Manor system. Further, WRT would handle replacement of the media in the ion exchange filters when such was needed, rather than regenerating the media on-site. This avoided the problem of a discharge of any wastes at the Chesdin Manor site, and placed responsibility for any media disposal on WRT. Finally, WRT would retain ownership of the ion exchange system, leasing the system to Fox Run, which presented some operational and financial benefits to Fox Run. One drawback was that WRT had applied several of their units for radium removal, but had only recently installed units for uranium removal. Therefore, WRT could not provide full-scale operational data from any uranium removal system in long-term operation. VDH determined that WRT would need to demonstrate performance of their system on a full-scale basis, before VDH would grant final approval. Fox Run selected WRT as their technology solution, in August 2004.

RESULTS

Because of the need to expedite the uranium removal system, a project team was formed that consisted of the various parties that would be involved in getting the system approved and constructed. The team included VDH, Fox Run, WRT, B & B Consulting (the engineering firm hired by Fox Run to develop the Preliminary Engineering Report and the plans and specifications for the project), and Dinwiddie County Water Authority (DCWA). DCWA joined the team, even though the County had no responsibility for the water system, in order to serve as an "honest broker" and to provide communication to the local government. The partners were in frequent contact in order to keep the project moving forward, discussing possible alternatives and installation procedures. Once the WRT system was chosen as the uranium removal technology, VDH agreed to allow Fox Run to proceed with installation of the units prior to formal approval of the engineering plans for the treatment system. Further, VDH offered two grants (one for planning/design and one for construction) from the Water Supply Assistance Grant Fund to help in paying for the project.

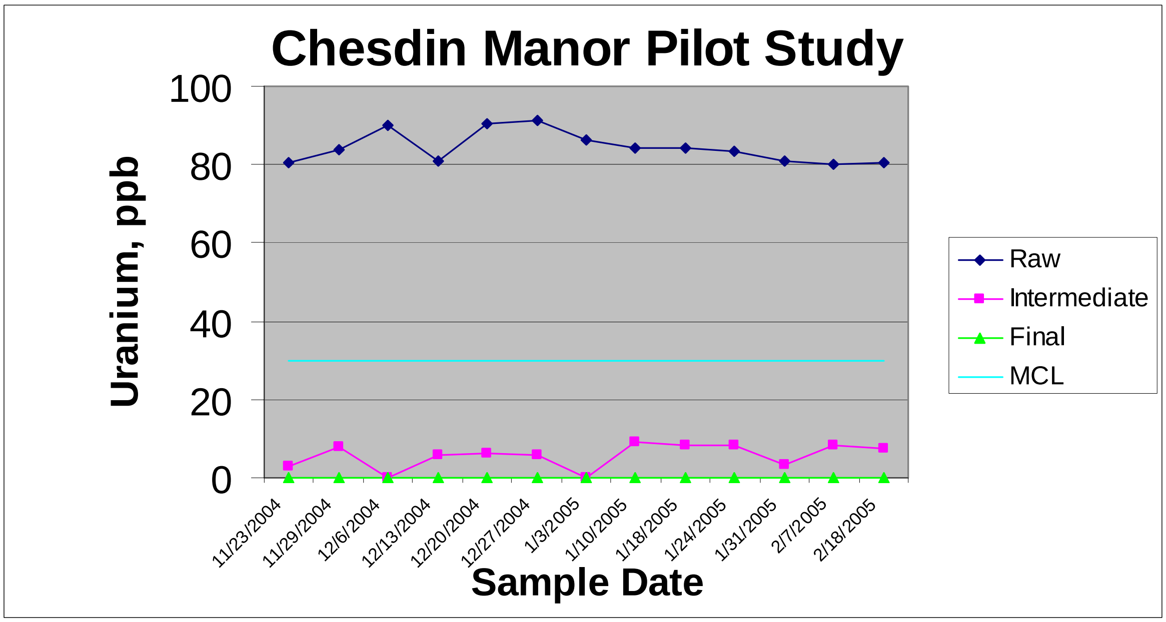
The technology selected consists of a two-stage upflow ion exchange system, utilizing a proprietary strong base anion media. The system would treat water only from one well, with that well pumping through the treatment system to the hydropneumatic tank, for delivery to the distribution system. The system includes two vertical fluidized bed vessels in series. Each vessel is 42 inches in diameter by 72 inches high, and is sized to handle 80 gpm, providing an empty bed contact time of 5.6 minutes and a hydraulic loading rate of 8.3 gpm/ft^2. A cartridge filter is installed after the second vessel, to capture any media fines that happen to escape the unit. The treatment system was constructed as a skid-mounted unit, to make installation at the site easier. Figure 1 shows the treatment system during the construction process at Chesdin Manor.

Figure 1 – Uranium removal units at Chesdin Manor

Fox Run spent the time from June 2004 to early August 2004 researching possible technologies that could be implemented at the Chesdin Manor system. They came to agreement with WRT in mid-August 2004, and fabrication of the treatment system began. Fox Run also needed to make modifications to their system in order to use the WRT system. A 90-day pilot test (full-scale demonstration) was developed, to determine the operating characteristics of the removal system. WRT and VDH negotiated the start-up procedures, and WRT developed an Operator's Manual to guide the pilot test and the long-term operations. DCWA agreed to serve as the sample collectors, as a neutral party who would be credible in the eyes of the system's consumers. Fox Run would make a decision later about bringing the second well into compliance with the uranium MCL.

The site modifications were completed in the first week of November 2004, and the WRT equipment was delivered to the site on 11 Nov 2004. The equipment skid was installed and connected to the site piping, the start-up completed, and the system placed into operation on 17 Nov 2004. That started the 90-day pilot test. The pilot protocol called for weekly sampling of the raw water, intermediate water (the water between the two columns), and the finished water. The testing during the pilot program showed that the raw water uranium ranged from 80.1 to 91.7 µg/L, the intermediate uranium ranged from < 1 to 9.1 µg/L, and the finished water was always < 1 µg/L (the level of detection). The presence of measurable uranium in the intermediate water is believed to be tied to media fines moving from filter 1 to filter 2. Figure 2 shows graphically the results from the pilot.

Figure 2 – Pilot Study Test Results



In order to determine the effect of the treatment system on the water being delivered to the consumers, a second set of samples was collected in February 2005, from the same homes that had been sampled in June 2004. The samples were mostly collected from kitchen taps used by the residents for drinking water. In four of the six homes, the "after treatment" results showed uranium to be < 1 µg/L (the detection level). In the other two homes, the measured uranium was 1.7 µg/L, or just above detection.

Based on the performance of the uranium removal system, leading to "below detection" levels of uranium in the water entering the distribution system and at the consumers' taps, the uranium removal project was declared a success in March 2005.

During the demonstration test of the WRT unit, samples were collected that indicated the presence of high levels of radon in the water, at concentrations greatly in excess of the AMCL proposed by EPA in 1999. The initial sample (in November 2004) showed the finished water from the uranium treatment system contained 7,300 pCi/L of radon, and follow-up confirmation sampling (in February 2005) showed finished water radon ranging from 15,500 to 17,000 pCi/L (there were four different labs involved in the analysis). Because the consumers had been highly sensitized to water quality issues as a result of the high uranium, VDH determined that the consumers needed to be made aware of the high radon as well, even though there is no current standard for radon in drinking water. VDH undertook to educate the residents about the risks posed by radon, and made test kits available to the residents so that they could do their own indoor air testing.

EPA Region 3 became aware of the high radon levels, and began pushing VDH to require early remediation for the radon in the drinking water. Region 3 even threatened enforcement action, under the authority of the "imminent and substantial endangerment" clause (§300i of the Safe Drinking Water Act). VDH noted that there was no enforceable standard, and continued to promote working cooperatively with Fox Run, rather than create an adversarial situation by resorting for an enforcement action. Region 3 has established a "concern threshold", indicated that any systems which exceed 10,000 pCi/L of radon in the drinking water would be expected to install treatment or otherwise remediate the water. It should be noted that other EPA regions apparently are not handling radon with the same level of concern.

Fox Run researched possible alternatives for radon removal, and has selected a shallow tray aeration system, manufacturer by North East Environmental Products. The design work for this project is currently in progress. The radon removal system will be installed between the uranium removal system and the bulk storage tank, which is to be placed into service. It is expected that construction will begin in the next six months. This portion of the project will also modify the system to allow treatment of the second well for uranium and radon removal, as well as other system enhancements.

DISCUSSION

The uranium removal system continues to provide excellent treatment, with finished water uranium continuing to be < 1 µg/L. Fox Run has moved to long-term operation, with quarterly samples being collected at the raw water, intermediate water, and finished water, as well as the quarterly compliance sample at the entry point to the system. WRT is monitoring the performance of the system, and will replace the media at such time as breakthrough begins to occur.

The residents were very concerned when they learned about the presence of uranium in their water. There were several "town hall" meetings where presentations were made by VDH and Fox Run to provide information about the situation. That went a long way to reduce fears of most residents, but there were some who continue to be concerned.

One point of concern for VDH relates to the radon issue. A number of the residents were very vocal about the presence of radon in the water in addition to the uranium. VDH urged the residents to do testing of their homes to see if there is an issue with radon in the indoor air. VDH made test kits available at two of the "town hall" meetings, and residents could also come to the local Health Department to obtain kits. Unfortunately, very few of the residents took advantage of the opportunity to have their indoor air tested. As the paper was being prepared, fewer than 10 homes had been tested. It appears that concern about radon in the water did not translate to concern about radon in the air, when some of that radon could come from the soil under the home itself.

CONCLUSIONS

The ion exchange system selected as the treatment option has performed very well, with all tests of the final effluent showing results less than detection. The system has effectively removed the uranium from the feed water.

This project shows the importance of a truly collaborative effort between a waterworks owner, his consultant, the manufacturer, and VDH. The team approach enabled the parties to discuss the various possible technologies, reach consensus about an approach, and implement that approach quickly. WRT's provision of data, including information about the proprietary media and preliminary performance data from other sites, enabled VDH to evaluate and accept the treatment system. VDH's decision to allow the installation of the treatment system in advance of the approval of the plans and specifications enabled the system to be in place and operating in less than five months from the time that the owner began searching for a solution to the uranium problem.

ACKNOWLEDGEMENTS

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