

Technical Background: Methods for Compliance with EPA Regulations

In 2000, the U.S. Environmental Protection Agency (EPA) issued new drinking water standards for certain radionuclides, including uranium. As drinking water treatment facilities comply with EPA's new limits for uranium in drinking water, some methods that may be used for compliance involve installing engineered treatment technologies. The removal of uranium from a diffuse source (i.e., diluted in groundwater) necessarily will concentrate the uranium in another place. The Atomic Energy Act of 1954, as amended, (AEA) provides NRC regulatory authority over uranium as source material (referred to as AEA material) once it is removed from its place in nature (i.e., artificially concentrated within or removed from the water stream). Depending upon the amount of concentration achieved, some of these technologies may require licensing by NRC or the Agreement States.

Under current regulations, there are three regulatory thresholds when considering AEA material: (1) a person is exempted from the regulations when possessing source material that remains under a concentration threshold of 0.05 percent by weight of uranium and thorium [10 CFR 40.13(a)]; (2) a person may operate under a general license if the amount of source material possessed at any one time contains less than 15 pounds of uranium and thorium and that same person receives (or in the case of drinking water facilities, extracts or concentrates) no more than 150 pounds of source material in a year [10 CFR 40.22(a)]; and (3) a person is required to operate under a specific license from NRC (or an Agreement State) for the possession and use of any source materials not covered by the exemption or general license. Due to the large quantities of water treated at even the smallest drinking water treatment plants, removal of even a low concentration of uranium can result in a waste stream containing hundreds of pounds of uranium. Only unusual circumstances will lead to a drinking water treatment plant being eligible for the existing general license, because the facility would have to be large enough to fall under EPA's rule (i.e., serve at least 15 service connections or 25 residents regularly year round), but still small enough to generate less than 150 pounds per year of uranium. In addition, such a facility would have to conduct its operations so as not to possess more than 15 pounds of uranium at any one time. Consequently, when evaluating technical methods for removing uranium from drinking water on a nationwide scale, the important regulatory threshold is considered to be the concentration limit of 0.05 percent by weight of uranium.

Methods for Removing Uranium from Drinking Water

As part of their 2000 rulemaking, EPA set two limits for uranium in drinking water: a maximum contaminant level (MCL) of 30 µg/L, and a maximum contaminant level goal (MCLG) of 0 µg/L. A MCLG is conservatively established at a level where there is no known or expected health effect. Because EPA uses a non-threshold linear risk model for ionizing radiation, all MCLGs for radionuclides are zero. MCLs are set as close to the MCLGs as possible, after consideration of cost and technological feasibility. To determine cost and technical feasibility, EPA evaluated specific treatment technologies. It should be noted that no one technology will be most effective to treat all affected waters, and the choice of technology will be dependent on site specific characteristics and limitations. Additionally, future developments may result in new technologies for removing uranium from drinking water that cannot be evaluated at this time.

Currently, the best available technologies (BATs) are ion exchange (IX), reverse osmosis, lime softening, and coagulation/filtration. A BAT list is published at 40 CFR 141.66, Table B. Small systems are allowed to use some technologies not on the BAT list, as published at 40 CFR

141.66, Table D. Regardless of the technology used, the process of removing uranium from drinking water will generate a waste, also called residuals, containing concentrated uranium. There are many variables that can affect the ultimate concentration of uranium in solid or liquid waste streams. The EPA does not publish a list of approved residual disposal methods or restrictions in the same way that the BAT list is published.

In general, the methods for complying with the uranium MCL can be categorized in light of the 0.05 percent by weight licensing threshold. At one extreme, technologies with a great affinity for uranium, such as ion exchange resins, will require specific licensing under NRC's current regulatory framework. At the other extreme, the drinking water facility operators may choose options that do not require the removal of any uranium from drinking water and, therefore, would not require licensing by NRC or the Agreement States. These options may include blending, modifying well construction, or using alternative water sources. Of the remaining technologies, operational parameters will determine if the 0.05 percent by weight threshold is breached.

Depending on the other considerations of the drinking water treatment plant, further concentration of uranium is also possible from the unit operations and processes used for residuals handling. In accordance with the appropriate permits, liquid residuals are most often disposed of at a sewage treatment plant, although they can sometimes be re-injected underground, or (rarely) discharged to a surface water body. Uranium may concentrate in excess of 0.05 percent by weight if the liquid residuals are not handled properly, such as in a buildup of pipe scale, or if the liquids are allowed to evaporate. Sludge, in general, is dewatered by mechanical means (centrifuge, filter press, or vacuum) or by evaporation (lagoon) before being applied to land or disposed of in an appropriate landfill.

Alternatives to Water Treatment

It is important to note that a drinking water system that is in violation of the EPA MCL for uranium is not compelled to install a treatment system. As part of their cost-benefit analysis, EPA estimates that 33 percent of the affected drinking water systems will not remove uranium from drinking water. EPA's estimate that 67 percent of affected systems will remove uranium is high, and the actual percentage of such systems treating for uranium may be much lower. Retrospective analyses for other drinking water standards (e.g., EPA's Notice of Data Availability (NODA) identifies specifically Illinois' experience with radium, and nationwide experience with nitrate/nitrates) have shown that approximately 25 percent of affected systems choose to treat their water; the other 75 percent use other methods such as using alternative water sources or blending water sources.

Where allowed, a drinking water treatment system may "blend" contaminated water with clean water so that the distributed, diluted, drinking water is in compliance with the EPA limits. Some States prohibit dilution as a compliance method. A more generally applicable option is to develop an alternative, non-contaminated, drinking water source. If a drinking water treatment system chooses to use an alternative water source or the blending option, uranium would not be extracted or concentrated and an NRC or Agreement State license will not be required.

Technologies that have Demonstrated the Generation of AEA Material

Ion exchange demonstrably concentrates uranium in excess of the “unimportant quantity” threshold of 0.05 percent uranium by weight. In an IX process, the uranium is concentrated on a resin as the water passes through the IX columns. Anecdotal evidence suggests that concentrations of up to 9.00 percent uranium by weight (180 times the regulatory threshold) may be retained on the IX resin. Currently, the few installed pilot programs at drinking water facilities throughout the country indicate that IX technology may be effective at removing uranium from many types of groundwater. More importantly from NRC’s regulatory perspective, the pilot programs provide evidence that IX technologies can concentrate uranium in excess of the 15 pound limit applicable to the general license in 10 CFR 40.22 within very short periods of time (weeks to months). Additionally, the EPA has noted [Technology Transfer Handbook: Management of Water Treatment Residuals, EPA/625/R-95/005, April 1996] examples where the IX regeneration waste (brine) is further concentrated in excess of AEA material thresholds. In experimental settings, average IX regeneration waste concentrations range from 0.02 percent to 0.20 percent by weight, with peak values of about 1 percent uranium by weight (20 times the regulatory threshold). Therefore, persons using such a technology will likely be required to obtain an NRC or Agreement State license.

Although it may be possible for a facility to use IX and not generate licensable concentrations of AEA material, it is not a very realistic consideration using current technology. Ion exchange resins can be regenerated, in exactly the same way a residential water softener is regenerated with a brine solution. As long as the uranium does not build up on the resin in excess of 0.05 percent by weight at any time, no license would be required; however, the practice of staying below this limit probably will not be cost-effective. To be effective, the IX resin must be regenerated with an efficiency near 100 percent (most likely at least 99.5 percent). Currently, EPA does not recognize a regeneration method whose efficiency exceeds 92 percent. Even hypothesizing the development of a sufficiently efficient method, such a regeneration schedule would only be for the purposes of regulatory compliance and have no relation to the considerable fundamental capacity of the resin for uranium. A higher regeneration frequency would affect operating and maintenance costs, and it would create a very large volume of wastewater. Additionally, more frequent flushes would create a greater opportunity for exposure to workers and increase the potential for incidents (such as localized spill). Because it is not in the best interest of the drinking water treatment facility to regenerate that frequently, it can be expected that any use of IX will very likely require a specific license from the NRC or an Agreement State.

Technologies Unlikely to Generate AEA Material

Technologies which generate a liquid waste stream and do not remove uranium selectively are unlikely to generate AEA material. Reverse osmosis (RO) is a BAT method that is not likely to generate AEA material, although it usually requires greater operator skill than IX and surface waters usually require pre-filtration. Reverse osmosis purifies water by forcing the water through a semi-permeable membrane under pressure. The membrane is designed so that both particles and dissolved ions are removed from the water, and are concentrated in a continuously produced liquid waste stream. Heavy metals such as uranium are removed by RO with very high efficiency. The liquid waste stream flow rate is typically about 1 percent of the incident flow rate, but the liquid waste stream flow rate can be adjusted for operational concerns. Based on the typical flow rate and the very high removal efficiency, the RO process

very likely concentrates uranium about 100x above the untreated groundwater. For regulatory purposes, a mass fraction of 0.05 percent uranium equates to a concentration in a liquid waste stream of 500 milligrams per liter (500 parts per million). Therefore, unless the raw groundwater is in excess of 5,000 micrograms per liter ($\mu\text{g/L}$) uranium, it is unlikely that RO alone will produce AEA material in its waste stream. EPA has noted (Technology Transfer Handbook: Management of Water Treatment Residuals, EPA/625/R-95/005, April 1996) uranium concentrations of about 0.01 percent by weight (1,000 $\mu\text{g/L}$ or 1/5 of the regulatory threshold) in the RO waste stream.

As with any liquid waste stream, if uranium is allowed to precipitate via pipe scale or excessive evaporation, there is a possibility of concentrating the uranium above the level for exemption. However, the residual waste stream is unlikely to generate AEA material as long as it is disposed of as a liquid, such as a discharge to sewage or underground injection.

Technologies that Could Generate AEA Material

Technologies for removing uranium from drinking water that generate a waste stream with sludge may, but are unlikely to, generate AEA licensable material. Lime softening and coagulation/filtration are two BAT methods that are not likely to generate licensable source material, because the uranium will not likely be concentrated in excess of 0.05 percent by weight. These technologies are unlikely to generate concentrated uranium because they do not remove uranium selectively. Instead, uranium (usually a trace contaminant) will be removed simultaneously with other naturally occurring impurities in the water, and therefore the sludge will likely be sufficiently diluted so that it does not exceed the 0.05 percent by weight threshold.

Unlike IX or RO, lime softening and coagulation/filtration do not remove uranium particularly well. Lime softening and coagulation/filtration are viable technologies because, for most affected waters, their removal efficiency is sufficient to meet the MCL. However, these technologies do not remove uranium as efficiently as RO and IX, which both approach 100 percent removal efficiency. This means that uranium is not retained as well in the residuals from coagulation/filtration and lime softening as in RO or IX. Another factor affecting the concentration of uranium is that lime softening and the coagulation process add non-radioactive chemicals (e.g., Al, Fe, Ca, Mg, polymers) to the process, which further act to dilute the uranium in the waste stream.

The use of lime softening and coagulation/filtration does not preclude the generation of licensable AEA material. Both technologies generate sludge, and depending on how the sludge is handled, the uranium may be concentrated above 0.05 percent by weight. However, only a combination of unusual circumstances would yield such an outcome. For this to occur for coagulation/filtration, the residual solids would have to be dewatered to a very high degree, up to or exceeding 20 percent solids content, roughly 10x the typical solids content of thickened coagulation/filtration residuals. This is because coagulation/filtration residuals are gelatinous, contain copious amounts of bonded water, and are extremely difficult to thicken/dewater. In the case of lime softening, the solids are considerably easier to dewater and may reach up to 70 percent solids with some effort; however, the lime that is added to the process will dilute the uranium. To generate licensable AEA material, the process chemicals such as lime would likely have to be recovered by unit operations. This practice is considered unlikely, but possible, and in any case should not generally exceed a concentration of 0.05 percent by weight uranium.

Other Technologies Requiring Additional Information

Activated alumina is not on the BAT list, but is another technology that has shown promise to remove uranium (40 CFR 141.66, Table D). Not much is known about the performance of activated alumina in treating for uranium at this time. Activated alumina is a technology that has developed over the past 10 years. It is not likely that activated alumina will concentrate uranium to the extent of IX, because uranium is not specifically removed. However, the potential remains that the waste stream from this process could still exceed concentrations that would require NRC licensing. Due to its overall operational restrictions at the current time, it appears unlikely that uranium would be removed from drinking water using activated alumina in the near future.