ENVIRONMENTAL PROTECTION URANIUM RECOVERY ISSUES IN THE UNITED STATES

R.T. Peake[1], A. Cherepy, R. Rosnick, D. Schultheisz, L. Setlow

[1] U.S. Environmental Protection Agency

MC: 6608J, 1200 Pennsylvania Ave, NW

Washington, DC 20460, USA

ABSTRACT

Uranium recovery activities in the United States were at a standstill just a few years ago. Demand for processed uranium yellowcake has increased, as has its price, though the price is down since the Fukushima reactor accident. Interest in producing uranium has increased, too. Currently the most preferred, low-cost uranium extraction method in the United States is in-situ leach (ISL) recovery where the geohydrology is conducive to injection, mobilization and pumping. A number of applications for new ISL and conventional mills have recently been submitted or are expected to be submitted for licensing by the Nuclear Regulatory Commission (NRC). In the United States, the Environmental Protection Agency (EPA) has developed Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings under the authority of the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA). These standards are found in the Code of Federal Regulations, Title 40, Part 192 (40 CFR Part 192). The NRC develops implementing regulations for 40 CFR Part 192 and then NRC or delegated States enforce the NRC and EPA regulations. Facilities regulated under 40 CFR Part 192 include conventional uranium and thorium mills as well as in-situ leach operations, which are considered to be "milling underground" for regulatory purposes. However, there are no explicit standards for ISL operations in 40 CFR Part 192. In addition, EPA has determined that portions of the operations at uranium recovery operations, specifically the radon emissions from tailings impoundments, are covered by Section 112 of the Clean Air Act as a source of hazardous air pollutants (HAPs). EPA addresses these operations in 40 CFR Part 61, Subpart W. EPA is in the process of reviewing both 40 CFR Part 192 and 40 CFR Part 61, Subpart W for possible revision. This paper presents some of the issues related to uranium recovery that are being considered in the current regulatory review.

1. INTRODUCTION

The United States Environmental Protection Agency (EPA or the Agency) has authority to regulate uranium recovery operations under several main legislative statutes: the Clean Air Act (CAA), the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), and the Atomic Energy Act of 1954 (AEA), as amended by UMTRCA.[1][2] Thus, EPA has standards that are issued under different statutory authorities for the same facility. This paper focuses on the CAA and UMTRCA authorities, which have some important differences regarding EPA responsibilities. EPA develops, implements, and enforces CAA requirements. Under UMTRCA, EPA develops the environmental standards (at 40 CFR Part 192) for uranium milling facilities while the Nuclear Regulatory Commission (NRC) develops the implementing regulations and regulates the uranium facilities, unless a State has entered into an agreement to implement NRC requirements (as an Agreement State). UMTRCA provides EPA with concurrence authority on NRC's implementing regulations, so NRC must get agreement from EPA before it finalizes its implementing standards.

EPA is in the process of reviewing both the 40 CFR Part 192 (hereafter 192) and 40 CFR Part 61, Subpart W (hereafter Subpart W) regulations due to a resurgent uranium industry. The 192 rule does not have explicit standards for in-situ leach operations, which are expected to be the most common type of uranium facilities in the United States. Subpart W is being revisited as part of a settlement agreement with plaintiffs who argued that EPA had not reviewed the Subpart requirements within the time period specified in the 1990 CAA Amendments.

2. URANIUM PROCESSING IN THE UNITED STATES

After Subpart W was promulgated in 1989, the price of uranium began to fall, and the uranium mining and milling industry essentially collapsed in the 1990s, with very few operations remaining in business. However, several years ago, because of renewed interest in nuclear power as a potential means to mitigate emissions of greenhouse gases, the price of uranium began to rise such that it became profitable once more for companies to consider uranium recovery. While below its high level attained just before the Fukushima, Japan reactor accident, the price of uranium (~$57 USD per pound as of May 13, 2011) is still profitable for many operators.[3]

In addition to conventional milling, many companies are now moving to more novel uranium extraction and recovery methods. In-situ leach recovery methods are already being applied at several locations in the United States; heap leach technology is currently being proposed at one location.

2.1 In-Situ Leach

In-situ leach or recovery (ISL/ISR, hereafter ISL) mining sites represent the majority of the uranium recovery operations that currently exist in the United States. The research and development projects and associated pilot projects of the 1980s demonstrated solution mining as a viable uranium recovery technique. The economics of solution mining produce a better return on the investment dollar and, therefore, the cost to produce uranium using this technology is more favorable to investors. As a result, the trend in uranium production is following the solution mining process.

ISL uranium mining is defined as the leaching or recovery of uranium from the host rock (typically sandstone) by chemicals, followed by recovery of uranium at the surface. Leaching, or more correctly the re-mobilization of uranium into solution, is accomplished through the injection of a lixiviant into the ore body. This injection essentially reverses the geochemical reactions that resulted in the formation of the uranium deposit. The lixiviant assures that the dissolved uranium, as well as other metals, remains in solution while it is collected from the mining zone through recovery wells. Figure 1 illustrates an idealized ISL operation.

Two types of lixiviant solutions are used in ISL recovery of uranium. These include acid and alkaline injections. In the United States, the geology and geochemistry of the majority of the uranium ore bodies favors the use of "alkaline" lixiviants or bicarbonate-carbonate lixiviant and oxygen. Other factors in the choice of the lixiviant are the uranium recovery efficiencies, operating costs, and the ability to achieve satisfactory groundwater restoration.

After processing, the recharged lixiviant is then pumped back down into the formation to be reused. However, a small amount of this solution is held back from reinjection to maintain a proper pressure gradient within the wellfield. It is sent to a lined impoundment (often called an evaporation pond) on site. Because this material contains uranium byproduct material[1], it is subject to the requirements of EPA's regulations. There is a risk of the lixiviant spreading beyond the zone of the uranium deposit, and this produces a risk of groundwater contamination. The operator of the ISL facility remediates this excursion by using large amounts of water to contain the excursion, and this water (often containing byproduct material) is often stored in the evaporation ponds, although if the excursion activities take place during or after closure of the processing facility, the impoundments would not be considered "operating" even though they continue to accept material.

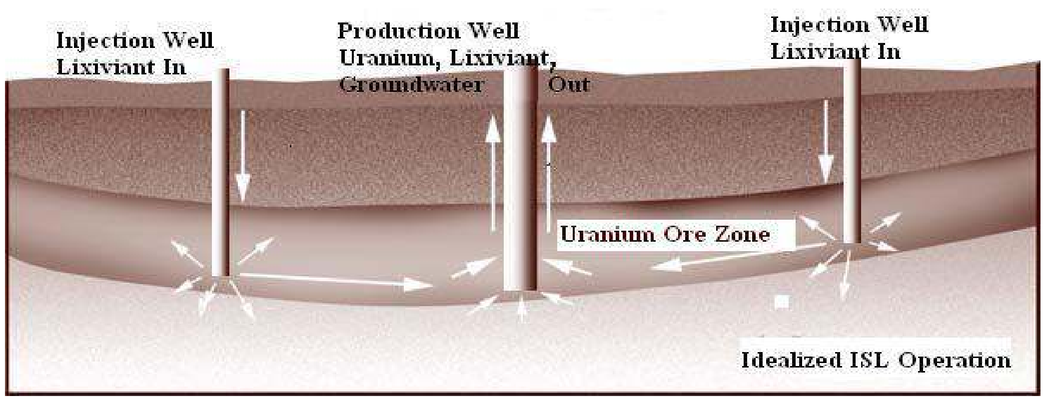

Figure 1. Idealized in-situ leach operation with a central pumping (producing) well and surrounding wells that inject liquids (lixiviant) to mobilize the uranium from the ore body into the groundwater toward the pumping well.

2.2 Heap Leach Piles

In addition to conventional uranium milling and in-situ recovery, which are both currently used to extract uranium from ore, some facilities may use extraction methods known as heap leaching (see Figure 2 for a simplified heap leach process diagram). No such facilities currently operate in the United States; there are, however, plans for one or two facilities to open. Regardless, heap leaching has been used to extract uranium from ore at conventional mills, and ion-exchange procedures have been used to separate uranium from the liquid extract at both conventional mills and ISL facilities.

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[1] Section 11.e(2) of the Atomic Energy Act defines byproduct material as "the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content."[2]

Heap leach/ion-exchange operations involve the following process:

1. Small pieces of uncrushed ore are placed in a "heap" on an impervious pad of plastic, clay, or asphalt, with perforated pipes under the heap.
2. An acidic solution is then sprayed over the ore to dissolve the uranium it contains.
3. The uranium-rich solution drains into the perforated pipes, where it is collected and transferred to an ion-exchange system.
4. The heap is "rested," meaning that there is a temporary cessation of application of lixiviant to allow for oxidation of the ore.
5. The ion-exchange system extracts and concentrates the uranium to produce a material, which is called "yellowcake" because of its yellowish color.
6. The yellowcake is packed in 55-gallon drums to be transported to a uranium conversion facility, where it is processed through the stages of the nuclear fuel cycle to produce fuel for use in nuclear power reactors.
7. Final drain down of the heap solutions occurs, as well as a possible rinsing of the heap.

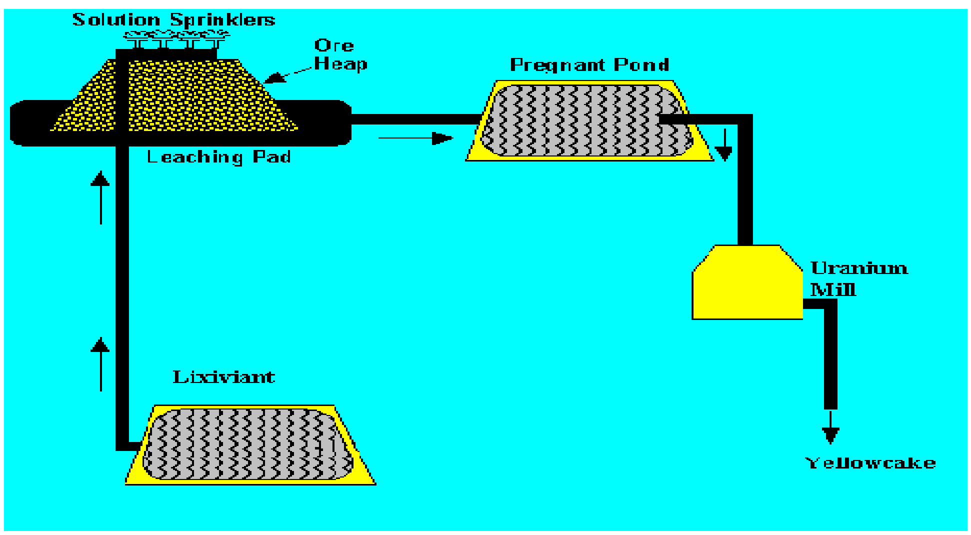

Figure 2. Simplified heap leach process diagram.

3. 40 CFR PART 61, SUBPART W

The CAA of 1970 required EPA to develop regulations for carcinogens, including radionuclides.[1] Under the CAA, 40 CFR Part 61, Subpart W was first promulgated in 1989 and addresses radon emissions from operating uranium mills and their associated tailings (defined in the regulations as any uranium byproduct material generated by the milling of uranium bearing ore).[4] Units regulated under this regulation include traditional uranium mill tailings piles, heap leach units, and certain evaporation ponds utilized in the ISL process. Units are subject to one of two standards, depending on the date on which they began operating. A radon emission standard applies for units in operation prior to December 15, 1989. Units constructed after December 15, 1989 must meet one of two work practice standards that limit radon emissions by covering portions of the units. As directed by the CAA Amendments of 1990, EPA is currently reviewing, and possibly revising, the Subpart W standards. A decision on whether to amend the standards will be made in 2011.

3.1 Radon Flux Standard

As noted above, tailings units are subject to one of two separate standards required in Subpart W. The first standard is for "existing" tailings piles, *i.e.*, those in existence prior to the promulgation of the standard (December 15, 1989). Those existing facilities must ensure that emissions from the tailings impoundments do not exceed a radon (Rn-222) flux standard of 20 $pCi/m^2 \cdot sec$. The method for analysis for radon flux was prescribed as Method 115, found at Part 61, Appendix B. More detail on Method 115 will be presented later in this paper. The owners or operators of existing impoundments are to report to EPA the results of the compliance testing for each calendar year by no later than March 31 of the following year. There is one existing operating mill with units that date to before December 15, 1989, and two mills that are currently in standby mode. Figure 3 shows a mill that operated in New Mexico, with the tailings impoundments clearly visible.

3.2 Work Practice Standard

The second standard in the existing Subpart W rule states that after December 15, 1989, no new tailings impoundment can be built unless it is designed, constructed and operated to meet one of two work practices:

1. Phased disposal in lined tailings impoundments that are no more than 40 acres in area and meet the requirements of 40 CFR 192.32(a) as determined by the NRC. The owner or operator shall have no more than two impoundments, including existing impoundments, in operation at any one time.
2. Continuous disposal of tailings that are dewatered and immediately disposed with no more than 10 acres uncovered at any time and operated in accordance with 40 CFR 192.32(a) as determined by the NRC.

The requirements at 40 CFR 192.32(a) incorporate by reference the design and operating requirements for surface impoundments managing hazardous waste, which were issued by EPA under the Resource Conservation and Recovery Act (RCRA).[5] These requirements include features such as liners and active monitoring to protect groundwater.[6] These requirements were included because UMTRCA required EPA's standards to address non-radiological constituents in a manner consistent with RCRA, but also prohibited EPA from requiring additional permits under RCRA.[2]

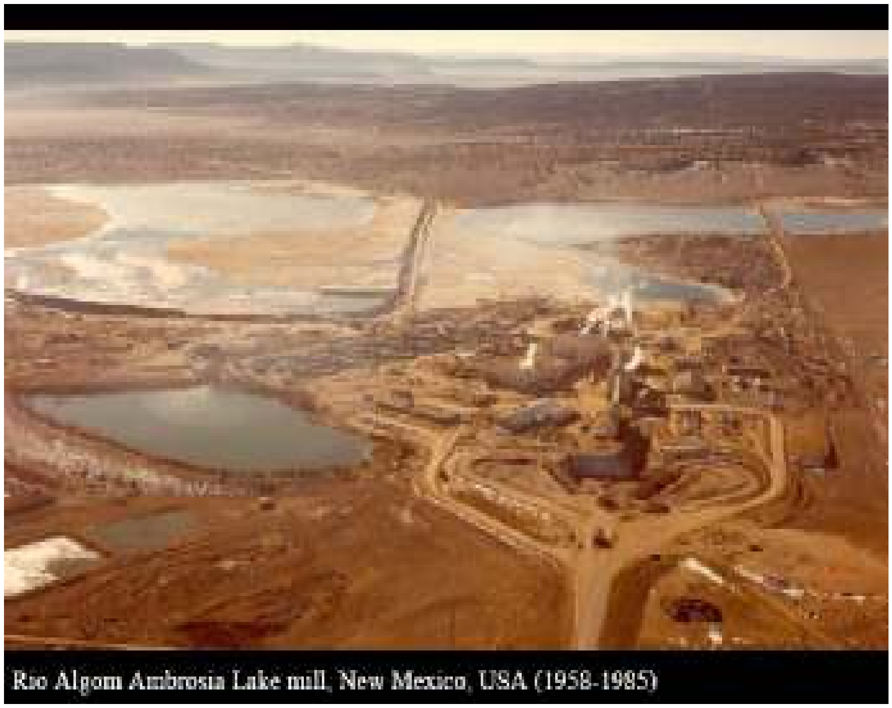

Figure 3. Conventional mill in New Mexico

3.3 ISSUES FOR SUBPART W REVIEW

3.3.1 Radon Flux Measurement Method 115

Method 115 is an approved testing method for determining radon flux from conventional tailings impoundments.[4] It employs Large Area Activated Carbon Canisters (LAACC) to collect radon emissions from the surface of dry tailings. If future impoundments are built, which utilize a continuous disposal or phased disposal approach, it is likely that Method 115 monitoring could also be applied. However, Method 115 is limited in that it only works on dry or partially dry tailings. Evaporation ponds are covered with liquid, so there is no solid surface on which to place the LAACC. Therefore, EPA will be collecting information on alternative monitoring methods applicable to tailings disposed into water, such as at lined evaporation or collection ponds. While there may be potential alternatives to the LAACC (such as the track-etch detector), no methods have been sufficiently demonstrated to be approved as suitable. There are indications that a liquid cover of a certain depth can be an effective radon barrier, so it is possible that this issue can be addressed through another work practice standard.

3.3.2 Heap Leach Options

Currently, there are no operating heap leach facilities in the United States, but the one proposed heap leach (Titan Uranium, Sheep Mountain, Wyoming) has been designed to meet current work practice requirements for conventional mill impoundments. However, the complication in applying Subpart W to heap leaching is the argument that the leach pile is part of the uranium extraction process, and not a waste pile. In this view, the heap is actively being processed to extract uranium and remains active until it is exhausted, even though byproduct material is present from the initial stage of processing. Therefore, the heap would transition directly from operations to closure, never falling under the requirements of Subpart W. In the alternative view, the applicability of Subpart W to the heap relies upon the strict language of the rule, which extends to "…facilities licensed to manage uranium byproduct material **during** (emphasis added) and following the processing of uranium ores…"

These issues are under consideration by the Agency as it develops possible approaches to a revision of Subpart W.

4. URANIUM MILL TAILINGS REGULATIONS AT 40 CFR PART 192

UMTRCA was passed to address concerns regarding the abandonment of uranium milling sites. There had been documented instances of removal and misuse of tailings, with potential for additional dispersal of the tailings into the environment. UMTRCA identified inactive milling sites to be studied, remediated, and brought under institutional control as appropriate.[2] As specified by UMTRCA, inactive uranium mills were to be remediated by the Department of Energy, utilizing specific EPA environmental and radiation protection standards. Separate EPA standards were to be utilized by the NRC in its oversight and licensing of operating and future uranium extraction facilities. In the latter case, the NRC is required to obtain EPA concurrence before it can issue its own final regulations for these facilities. EPA published its 40 CFR Part 192 standards in 1983, with a revision in 1995 to address groundwater remediation. The 192 regulation provides standards for protection of: surface water, groundwater, air (radon), surface soils and buildings, and public health; design, monitoring, operation, corrective action and closure requirements are also included.[7]

As UMTRCA provides for NRC to serve as the regulatory authority for administering EPA's standards for uranium and thorium milling facilities, a balance must be achieved in the extent of EPA's standard setting and NRC's discretion in administering and enforcing the day-to-day oversight of operations. NRC must also ensure that its regulations comply with its own statutory mandate, which requires that NRC manage the "byproduct material" at these facilities "in such manner as":

(1) the Commission deems appropriate to protect the public health and safety and the environment from radiological and nonradiological hazards associated with the processing and with the possession and transfer of such material taking into account the risk to the public health, safety, and the environment, with due consideration of the economic costs and such other factors as the Commission determines to be appropriate;
(2) conforms with applicable general standards promulgated by the Administrator of the Environmental Protection Agency under section 275 [of the Atomic Energy Act]; and
(3) conforms to general requirements established by the Commission, <u>with the concurrence of the Administrator</u>, which are, to the maximum extent practicable, at least comparable to requirements applicable to the possession, transfer, and disposal of similar hazardous

material regulated by the Administrator under the Solid Waste Disposal Act [now RCRA], as amended."[2 (emphasis added)]

4.1 40 CFR Part 192 In-Situ Leach Issues

The Agency has begun to review the various standards in 40 CFR Part 192 in light of data gathered over the last 25 years. This includes information on how well the regulations have worked, changes in operating practices and technologies used by industry, changes in dose and risk factors associated with the radionuclides of concern in uranium and thorium extraction, judicial rulings concerning parts of the regulation, and changes in drinking water protection standards. Of these issues, the primary matter under review by EPA, and the focus of this discussion, is the need for specific requirements (particularly for groundwater) pertaining to NRC or Agreement State licensed ISL operations, that would address the length of post-closure monitoring needed to ensure stability of the containments.[2]

When the regulation was written in 1983, the ISL uranium extraction process was not commonly used in the United States; there were no specific standards addressing the particular requirements that may be necessary for in-situ leach operations. Because the "milling" of uranium ore is performed within the aquifer by injection of mobilizing agents, ISL facilities present challenges for groundwater protection that are distinct from those posed by conventional mills. Furthermore, the intent of ISL operators is to release the site and make it available for other uses after additional processing of ore is no longer economically viable. This is in contrast to conventional mill tailings for which tailings covers need to last for at least 200 years. Given the disruption of the aquifer inherent in ISL technology and the foreseeable desire for a relatively short period of post-operational institutional control, groundwater protection will be of central importance in amendments to 40 CFR Part 192.

Two issues that EPA is contemplating, but for which no decisions have been made, involve the related matters of how long well-monitoring should continue after uranium recovery operations are complete and how the operator can demonstrate compliance with the restoration goals.

4.1.1 Duration of Post-Operational Monitoring

EPA's requirements must ensure that operators monitor for a sufficient period of time to establish that the standards have been met, that aquifer stability has been achieved, and that there is confidence that conditions will not degrade. The time necessary to achieve these goals will depend on site-specific factors; however, some basic parameters can be described to frame the issue and its implementation. Currently, NRC leaves it up to the operator to determine the length of time for monitoring; it may be as short as one year.[9] However, as noted previously, UMTRCA requires that EPA develop standards that are consistent, to the maximum extent possible, for non-radioactive hazardous substances with the requirements for RCRA Subtitle C

[2] ISL operations are required to obtain a separate regulatory approval for the wells used to inject the lixiviant. These wells are permitted by EPA or delegated States under the Safe Drinking Water Act. However, UMTRCA is the controlling authority for post-operational restoration of the aquifer.[8]

hazardous waste facilities (found in 40 CFR Part 264). [2] If an in-situ leach facility is considered equivalent to a RCRA hazardous waste facility that has already had releases in a solid waste management unit, then under the minimum monitoring period for the corrective action requirements in 40 CFR Part 264.96, an ISL operator would have to demonstrate that the groundwater protection standard is not exceeded for three consecutive years.[6] The specific amount of time that an operator may be required to monitor beyond three years would depend on site conditions and the response of the constituents of concern.

4.1.2 Demonstration of Compliance

Identifying the target constituent concentrations and the monitoring period are necessary, but not sufficient conditions for determining compliance with the standards. A determination of compliance must also take into account the size of the well field, the number of wells and data points, variability of data, baseline conditions, and other factors to provide the necessary confidence in the decision. Statistical measures (data demands and uncertainty levels) also need to be considered in order to make decisions on whether the aquifer has returned to original conditions or when changes from baseline conditions have reached steady-state levels and decisions about degradation of the aquifer water quality can be justified. In other words, how do we determine that the constituents of concern are stable and unlikely to increase in the future? As part of the regulatory process, EPA has asked the Agency's Science Advisory Board to weigh in on this issue.[3]

5. CONCLUSION

Over the last several years, there has been renewed interest in uranium recovery in the United States. In-situ leach recovery has received most of this interest and a significant number of license applications for new ISL operations have been submitted to the NRC or its Agreement States. As a result, groups opposed to the industry efforts are becoming more active as well. EPA is responding to industry and stakeholder issues by reviewing its CAA and UMTRCA regulations to identify whether they are still protective of human and environmental health and appropriate for the ISL technology. The ISL recovery process was not a major technology used when EPA first developed its regulations in the 1980s and it may be appropriate to update the regulations to reflect changes in the industry.

6. REFERENCES

[1.] Clean Air Act of 1970, as amended, United States Code , Title 42, Section 7401 et seq.

[2.] Atomic Energy Act of 1954, as amended by the Uranium Mill Tailings Radiation Control Act of 1978, United States Code, Title 42, Section 2011 et seq.

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[3] The Science Advisory Board (SAB) is an independent body of non-EPA experts whose purpose is to provide technical advice in the development of EPA standards or products, or to review completed products and projects for technical adequacy. The Radiation Advisory Committee (RAC) is a subcommittee of the SAB that focuses on radiation issues.

[3.] TradeTech, http://www.uranium.info, accessed May 20, 2011.

[4.] Code of Federal Regulations, Title 40, Part 61, Subpart W, "National Emission Standard for Radon Emissions from Operating Mill Tailings.".

[5.] Resource Conservation and Recovery Act, United States Code , Title 42, Section 6901 et seq.

[6.] Code of Federal Regulations, Title 40, Part 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities."

[7.] Code of Federal Regulations, Title 40, Part 192, "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings."

[8.] Safe Drinking Water Act, United States Code , Title 42, Section 300f et seq.

[9.] Lusher, J., "Standard Review Plan for In Situ Leach Uranium Extraction License Applications," NUREG-1569, Nuclear Regulatory Commission, 2003.