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By email attachment - pdf
Air and Radiation Docket,
Environmental Protection Agency,
Mailcode: 2822T, 1200 Pennsylvania Ave. NW.
Washington, DC 20460
email: a-and-r-docket@epa.gov

RE: Comments on Rulemaking Docket ID No. EPA–HQ–OAR–2008–0218; Clean Air Act Regulation of Radon Emissions from Uranium Mill Tailings

These comments are submitted on behalf of Colorado Citizens Against ToxicWaste ("CCAT") Grand Canyon Trust, and the Rocky Mountain Chapter of Sierra Club.

Summary of Comments

Comprehensive review of National Emission Standards for Hazardous Air Pollutants ("NESHAP") regulations applicable to uranium processing wastes was mandated by the 1990 Clean Air Act Amendments ("CAAA"). The mandate was a direct response to the Environmental Protection Agency's ("EPA") refusal to adopt effective NESHAP regulations in the 1980s.

The present review and revision of the Clean Air Act rules applicable to uranium tailings was prompted by a 2007 lawsuit brought CCAT, which is located in the Cañon City, Colorado community directly impacted by the inadequate standards contained in Subpart W. EPA–HQ–OAR–2008–0218–0013, EPA–HQ–OAR–2008–0218–0019. Despite settlement promises of prompt action in 2009, EPA's failure to commit adequate resources to the rulemaking effort resulted in five more years of delay. Unfortunately, the draft rule prepared by EPA's Office of Radiation and Indoor Air, Radiation Protection Division ("ORIA") continues to ignore Clean Air Act ("CAA") requirements and community concerns. In short, the proposed rule effectively eliminates CAA NESHAP regulation, monitoring, and control of radon emissions from uranium mill wastes. Key features of CAA and NESHAPs applicable to other hazardous air pollutants and area sources - control technologies, emissions limits, monitoring, and reporting – are omitted from the proposed rule. The proposed rule does not justify the radical and nearly complete departure from the purpose and structure of the CAA NESHAP program.

These comments are based largely on the information and experience gained by the communities in the airsheds and watersheds containing Cotter Uranium Mill near Cañon City, Colorado and the Energy Fuels Uranium Mill near White Mesa, Utah. Unfortunately, OIRA declined invitations to send representatives to either community to discuss the proposed rule. Had OIRA held hearings in these communities, EPA would have gained information about the actual emissions from these milling wastes, some of which is contained in EPA files. The community

knowledge, which is quite sophisticated, confirms that OIPA's proposal to eliminate monitoring and emissions limits and change some definitions cannot effectively repair inadequacies, gaps, and ambiguities in current NESHAPs, as they apply to conventional mill tailings in private ownership. Comments were provided by the few community members that were able to attend the single rulemaking hearing, held in downtown Denver, Colorado, blocks away from the offices of the uranium industry and the National Mining Association and hundreds of miles from the impacted communities. The community statements are incorporated here by reference.

EPA's rulemaking records do not contain available and obtainable data from the Cotter and Energy Fuels mills that is necessary for EPA to make an informed decision on whether or not the existing regulations have resulted in unnecessary radon emissions and groundwater contamination. The observations and experience of the impacted communities confirm that radon emissions are largely uncontrolled while tailings are 'stored' in open-air impoundments without adequate cover. Cotter recently demolished its mill and dumped it into the uranium tailings impoundments, but there is no approved plan or timeline for installing a permanent cover. EPA has done nothing to monitor or control radon emissions at Cotter, even though the leaking tailing impoundments are being dewatered while other impoundments receive contaminated groundwater and other wastes. An approved plan for permanent radon barrier does not exist for the impoundments near Cañon City or White Mesa. Due to the lack of state or federal enforcement in Utah, Grand Canyon Trust brought a CAA citizen enforcement action seeking to remedy repeated exceedances of the 20 pCi/m2/sec emissions limits, reporting requirements, and the work practice standards limiting the number and acreage of the open-air tailings dumps. Exh. 1 (First Amended Complaint).

Groundwater contamination remains an ongoing problem at every closed and operating tailings impoundment where saturation and water cover was used as a "control technology." By continuing the 1950s practice of open air dumping with water cover, the proposed rule ignores 21st Century "control technology" and "management practices" that could eliminate and minimize both radon emissions and groundwater contamination caused by keeping talc-like uranium wastes saturated and covered with water, often for decades. Continuous cover, paste tailings, dry placement, and solidification are among the alternative technologies that are not identified or considered in the proposed rule, despite repeated requests by impacted communities.

The present rule has failed to achieve the EPA's previously-stated goal of eliminating the industry practice of leaving uranium tailings in open-air storage, without permanent cover, for decades. Due to gaps and arbitrary distinctions between operating and non-operating tailings cells carried through into the current regulations, the Clean Air Act goal of minimizing or eliminating radon emissions has not been achieved. Instead of maintaining two sets of regulations applicable to privately owned uranium wastes – Subpart W and Subpart T – actual conditions warrant a new rule that sets a single, comprehensive emissions limit and monitoring requirement for disposal of uranium processing wastes.

These comments also echo and incorporate by reference the comments by the Office of Management and Budget, including the concern that EPA has not explained or justified the decision to forego an emissions limit. The current monitoring and enforcement gaps created by

Subpart W and Subpart T resulted in delayed closure and has not minimized or eliminated radon emissions at the Cotter and Energy Fuels facility. Where the current record confirms the failure of a regulatory scheme adopted in 1989, EPA should adopt an interim emission limit of 10 pCi/m2/sec based on Method 115 monitoring and reporting requirements for all private tailings impoundments while EPA prepares a new draft. According to the regulated industry comments contained in the record, a 10 pCi/m2/sec emissions limit is currently achievable at conventional mills, even without modern control technology.

Although EPA did not carry out a review of available control technologies, the existing record confirms that that an emission limit of less than 10 pCi/m2/sec is warranted. Sources of information include the tailings handling and proposals used by industries that have been active in the 21st Century. EPA ignored other sources of information that support a lowered numeric standard, incluing the control technologies employed by the Department of Energy, which is actively placing tailings from Moab, Utah into the Crescent Junction, Utah tailings facility using a continuous cover work practice. DOE has data from placement and monitoring of tailings from numerous other sites now in DOE's perpetual care and maintenance, which are subject to a 20 pCi/m2/sec standard that DOE presumably confirms is being met by regularly taking radon flux measurements. 40 C.F.R. § 192.32(b).

A new rule should be drafted to address existing regulatory gaps that lead to indefinitely open tailings cells by adopting a single NESHAP regulation to replace Subpart T and Subpart W that ensures elimination or minimization of radon emissions for the entire period of private ownership. Private ownership typically ends after closure when permanent radon barrier is completed and proven effective and the private license is terminated. 40 C.F.R. § 192.32(a)(4)(i). In short, comprehensive rewrite of NESHAPS applicable to conventional mills is warranted based on ineffective implementation of 40 C.F.R. Part 192, which lacks the citizen enforcement provisions of the Clean Air Act. These regulatory gaps, ineffective implementation, and lack of enforceability was not revealed by EPA's narrow review of Subpart W, which was based on an arbitrarily limited data set.

These comments support EPA's confirmation that in-situ leach facilities are subject to EPA's Clean Air Act NESHAP jurisdiction. However, where the rule does not include emissions limits confirmed by monitoring and reporting requirements, EPA has carried out its Clean Air Act duty to minimize or eliminate radon emissions. The comments also support NESHAP regulation of radon from heap leach projects; although it is likely that open-air heap acid leaching of uranium is a not a viable industrial practice where "technologies" such as enclosures are available.

In sum, the conventional milling component of these comments request that the Administrator take action to satisfy EPA's CAA duties and to comply with the settlement agreement by:

1) withdrawing the proposed rule and entering a finding that the rulemaking record confirms that Subpart T and Subpart W do not satisfy CAA NESHAP requirements;

2) gathering information necessary to minimize and eliminate radon emissions from uranium processing wastes;

3) dedicating the necessary agency resources to work cooperatively with impacted communities to comprehensively revise NESHAPs applicable to effectively reduce and eliminate radon emissions from uranium processing facilities without impacting groundwater; and,

4) dedicating the necessary agency resources to publish and adopt an effective rule before July 1, 2015.

Existing and Proposed NESHAP Regulations Improperly Exclude Emission Limits and Measurements

Radon in uranium tailings has a well-established impact on human health.

> The radon concentration present in mill tailings can be up to 1,000 times higher than the concentration in natural soils (Ferry et al. 2002). Because radon has been classified as a Group 1 human carcinogen by the International Agency on Cancer Research, regulatory agencies have enacted limits on the radon releases from mill tailing sites (IACR 1988).

Exh. 2 Altic, Nickolas, Pilot Study Report for Radon Exhalation Measurements (2014) at 1. The hazardous characteristics of radon and its decay progeny is confirmed in the National Environmental Policy Act documents rulemaking record prepared in the 1980s for support of 1989 radon emissions NESHAPs. Unfortunately, the currently proposed rule deviates from those findings without revising or updating the 1980s-era studies.

Instead, the proposed rule relies on cursory overview of a limited set of data and unreliable risk assessments prepared by third-party contractors with close ties to the regulated uranium industry. The rulemaking record indicates that EPA experts spent little or no time gathering data or conducting scientific analysis for the proposed rule. As a result, an informed and reasoned decision to forego emissions limits and monitoring requirements cannot be based on the erroneous and unreasonably narrow scope of data contained in the current rulemaking record. Where EPA scientists have contributed almost nothing to the rulemaking record, there is no basis to reduce NESHAP regulatory requirements based on 1980s-era the health impacts analysis.

Instead, the data and scientific analysis contained in the 1980s rulemaking records, combined with available data, compels a determination that radon from uranium mill processing wastes requires an emissions in the range of 1 to 5 pCi/m2/sec based on presently deployed and available control technologies. In the EPA analysis prepared in the1980s, limits as low as 2 pCi/m2/sec were confirmed as protective of human health, but EPA chose a higher limit and work practices based on industry's economic arguments. 54 Fed. Reg. 9637-9638 (Draft Rule discussing protective standards and limits as low as 2 pCi/m2/sec), 54 FR 51654 (Final rule setting a limit 10 times higher than the 2 pCi/m2/sec limit). EPA did not update any of the industry cost data from the 1989 rulemaking, and has no current basis to reduce the standards below what is protective of human health.

Where EPA removes emissions limits and ignores the technology-forcing health benefits of numeric standards, the EPA proposal runs contrary to the agency's science, previous regulatory

determinations, and Clean Air Act mandates. These factors compel EPA to continue to regulate radon at uranium mills as a hazardous air pollutant, until and unless the agency determines the source category is no longer necessary and makes the necessary determinations to remove these sources from NESHAP regulation. Of course, data in the rulemaking record prevents EPA from lawfully removing uranium mill tailings facilities from NESHAP regulation. The proposal to eliminate numeric emissions standards and monitoring has the effect of removing radon from uranium tailings, a regulatory action which could not be achieved under the standards applicable to NESHAP deletions.

The Clean Air Act provides Clear Authority to Regulate Radon Emissions

Comments of the regulated industry argue that EPA does not have authority to directly regulate radon emissions from uranium processing facilities. The industry's arguments provides statutory basis to stripping EPA of its Clean Air Act authority over uranium mill tailings, relying instead on cherry-picked agency memos taken out of context. As above, if industry wishes to remove a tailings facility from NESHAP regulation, it should submit a petition showing that radon emissions are not hazardous. Of course, this effort would fail. Fortunately, EPA's proposed rule continues to recognize the health hazards of uncontrolled radon emissions from uranium mill tailings and the rulemaking record confirms that CAA NESHAP regulation is a necessary part of EPA's role in regulating uranium mill tailings pursuant to its Clean Air Act and Uranium Mill Tailings Radiation Control Act authorities.

The industry's argument appears to be an attempt to shift all authority to NRC and thereby avoid the CAA's robust enforcement provisions, which unlike NRC's program, includes citizen enforcement. The uranium industry argues for regulation solely under the Atomic Energy Act and UMTRCA authorities, which has proven ineffective at accomplishing timely closure of numerous tailings facilities, including Shootaring Canyon, Cotter, Wite Mesa and Sweetwater, all of which involve tailings cells that have lingered on so-called "standby" without final radon barriers or closure plans. Despite EPA's Part 192 regulations, uranium tailings cells still remain idle and unmonitored without proven or final radon barriers, often for decades. 40 C.F.R. § 192.32.

In order to avoid unnecessary regulatory gaps and jurisdictional confusion between CAA and UMTRCA regulation, EPA's belated 1990 CAAA rulemaking should eliminate the artificial distinction between Subpart W and Subpart T and require that all privately owned tailings cells comply with the typical CAA numeric standards framework, regardless of operating, closure, or standby status. The alteration of NESHAP regulation based on a company's stated intent is not warranted and should be precluded where tailings cells linger for decades, uncovered, unclosed, and inactive based on a bare assertion that the facility may reopen, someday.

Information in the rulemaking record confirms that separate CAA regulations for impoundments that are "operating" and "in closure" does not serve the purposes of either UMTRCA or the Clean Air Act, both of which seek to reduce, minimize, and eliminate hazardous emissions, including radon. 42 U.S.C. § 7412(d), 42 U.S.C. § 7901. Where EPA has CAA authority over privately owned uranium tailings, the NESHAP rules should be structured to achieve UMTRCA and CAA statutory goals by setting CAA numeric emissions limit coupled with reporting

requirements and enforcement regime. Unfortunately, EPA's proposed regulation needlessly and without explanation abandons these basic CAA tools and leave uranium mill technologies stuck in a Cold-War era open-air storage and disposal regime.

EPA Failed to Provide Transparency and Robust Community Involvement

The rulemaking was initiated based on a 2009 settlement agreement reached with CCAT where EPA promised the agency would conduct an open and inclusive rulemaking. However, the proposed rule was developed without EPA's meaningful engagement with the impacted communities.

Throughout the comment period, and until CCAT took steps toward judicial enforcement of the settlement, EPA did not provide access to non-privileged agency records. In 2014, at the very end of the comment period, EPA confirmed OIAR violations of the settlement and began releasing, in bulk, the non-privileged agency records created and obtained during the five-year span of rulemaking. I In an belated effort to respond to CCAT complaints, EPA personnel from the Washington D.C. Office met with CCAT while in Denver for the public comment hearing. The meeting involved what appeared at the time to be a sincere effort by EPA staff to understand the past impacts and ongoing emissions at tailings piles at the now-demolished Cotter Mill in Canon City, Colorado. CCAT representatives told EPA staff that Cotter's impoundments are still actively receiving 11e2 byproduct, including buildings, soils, and uranium-contaminated groundwater from an active pumpback system. EPA has not followed up or made any subsequent attempt to address or consider the ongoing radon emissions at Cotter, which repeatedly exceed the 20 pCi/m2/sec flux standard used throughout EPA's radon regulatory scheme.

During the rulemaking hearing, EPA staff did acknowledge that impacted communities are asking for a comprehensive rebuilding of the NEPSHAP regulations to ensure Clean Air Act purposes and mandates are met. To paraphrase an EPA staffer's astute summary made outside the hearing: what the impacted communities request is that EPA conduct a tear-down and rebuild, not a remodel. In the hearing, EPA staff requested that CCAT prepare an alternate set of regulations. If provided the adequate time and resources, the commenting groups would enjoy working with a coalition of other impacted communities and EPA technical staff to develop a proposed rule based on compliance with Clean Air Act mandates. A community-led rebuild of the NESHAP rules could correct fundamental flaws in the structure and detail in the 1989 regulations and the pending EPA proposal. Because Environmental Justice concerns are implicated, EPA programs such as NEJAC could provide play a role to leverage other EPA funding sources and provide a framework, resources, and technical support for such an effort.

Unfortunately, real community involvement remains an empty prospect and unlikely based on a series of unfulfilled EPA promises. EPA has not sought to address the concerns of the other impacted communities in Utah, Colorado, Wyoming, South Dakota, Nebraska, Texas, Arizona, and New Mexico that did not bring legal action. EPA's refusal to reach out and hear community concerns during rulemaking on the Clean Air Act regulation of radon emissions from uranium mill tailings continues a legacy of environmental injustice. If EPA had provided a forum, local and regional communities would have undoubtedly made their voices heard. Indeed, a

community meeting about EPA's proposed Subpart W Rule was held on October 23, 2014 in White Mesa, Utah by the Grand Canyon Trust and Uranium Watch. The community meeting was attended by over thirty interested citizens from the Four Corners Region, including numerous Ute Mountain Ute tribal members.

In 2014, communities still bear the burdens of hazardous radon emissions, while companies and the federal government continue to reap the benefits of cheap and dirty yellowcake production that began with the Manhattan Project, the Cold War, and the promise of energy production "too cheap to meter." EPA's treatment of communities burdened by uranium mill tailings stands in stark contrast to EPA's Environmental Justice policies and promises, as well as Executive Orders.

Work Practices Require Numeric Standards based on Available Technologies

Read carefully, the present proposal is not based on any type of available control technology. Water cover and limited size and number of tailings ponds are not "control technology," as that term is used in the CAA. Size and number of impoundments are "work practice" standards carried over from the stale 1989 rule. These work practices are, at best, archaic industry practices of an industry gone largely dormant due to the low grade/high cost U.S. uranium ores that lack value in a competitive global market.

Without any reference to the record and in direct contradiction to facts well known to EPA staff and impacted communities, "the proposed GACT for conventional impoundments retains **the two work practice standards** and the requirements of 40 CFR 192.32(a)(1), because they **have proven to be effective methods for limiting radon emissions while also protecting ground water**." EIA-BID at 64 (emphasis supplied). Even the sparse rulemaking record confirms the alleged "effectiveness" not proven and is demonstrably false. The current regulatory scheme has not limited radon emissions where ongoing violations exist at the Cotter and Energy Fuels mills. EPA does not point to a single conventional uranium mill that has not caused groundwater contamination. Simply put, EPA's basis for the proposed rule is contrary to established fact.

EPA's renaming of the "work practices" from the present rule into a "control technology" does not avoid the requirement that **a "[work practice or similar] standard […] shall be promulgated in terms of a [numeric] emission standard whenever it is feasible** to promulgate and enforce a standard in such terms." 42 U.S.C. § 7412 (h)(4)(emphasis supplied). The misplaced intent of the revised rule to continue using 1989 work practices without numeric standards is confirmed by the rulemaking record as applied to ISL facilities: "By incorporating these impoundments under the work practice standards, the requirement of radon flux testing is no longer needed and will be eliminated." EIA-BID at 63. Where an array of feasible means exist to promulgate numeric standards and then measure, report, and enforce radon flux standards in accordance with the normal CAA framework, EPA does not have discretion to dispense with radon flux testing or numeric limits.

No Rationale is Provided for Choosing GACT over MACT

The proposed rule does not explain how EPA exercised its discretion in choosing a Generally Available Control Technology ("GACT") instead of a Maximum Achievable Control Technology ("MACT"). EIA-BID at 61- 63 (discussing standards). Although the CAA does provide some discretion to deviate from presumable application of MACT to hazardous air pollutants, merely asserting GACT can be used for uranium tailings without providing some type of reasoned basis for the decision to use GACT violates basic rulemaking requirements of the CAA and the Administrative Procedure Act. 5 U.S.C. § 701, *et. seq.*

Whichever "control technology" may eventually be used to set the numeric emissions limit, an array of available technologies exist to reduce and eliminate radon emissions without the well-established groundwater contamination that comes with using water cover as a "control technology." For example, paste tailings and cemented tailings provide a means to place tailings in an impoundment without liquids, and are appropriate for immediate placement of a continuous radon barrier without a dewatering period. *See e.g*. Exh. 3 Dudgeon, Disposal of Uranium Tailings as Paste (1999), Exh. 4 P. Moran, Cemented Tailings Backfill – It's Better, Now Prove It! (2013). These and other methods are used by mineral processing industries that have been active since 1989. In countries with uranium ore deposits supporting active conventional uranium milling after 1989, technologies that do not involve the notoriously ineffective water cover approach are being used to stabilize and control uranium mill tailings. None of the post-1989 technological advancements are analyzed in the rulemaking record, with new technologies brushed off with a conclusory sentence addressing alternate cover techniques. EIA-BID at 30 *citing* NRC "Workshop on Engineered Barrier Performance Related to Low-Level Radioactive Waste, Decommissioning, and Uranium Mill Tailings Facilities," ML101830458, August 3–5, 2010.

It is unlikely that the United States will ever see a resurgence of conventional milling due to the low quality ores and high processing costs. Nevertheless, EPA is required by the CAA and principles of Environmental Justice to ensure that numeric standards for privately owned tailings cells are set based on available technologies used, sometimes by U.S. firms, in Australia, Canada, and other countries with an active conventional uranium milling industry. Although it is often presumed the United States is a technology leader, EPA's current proposal lags behind the rest of the world by several decades. The proposed rule ignores existing tailings handling and disposal systems that would serve the "technology-forcing" structure and purpose of the Clean Air Act, which depends on setting numeric standards and limits.

EPA's decision to choose GACT is particularly unacceptable in light of its failure to comply with the requirements of 42 U.S.C. § 7412(c)(1) – the list of source categories. EPA is required to publish a list of all categories and subcategories of major source and areas sources of radionuclides and/or radon. This requirement forms the basic foundation for EPA's regulation of these hazardous air pollutants. However, EPA has not complied with this requirement with respect to uranium mills as a source category of radionuclide emissions. EPA must comply with the mandates of 42 U.S.C. § 7412(c)(1) with respect to radon and uranium mills before it can justify its choice of GACT rather than MACT standards in its proposed rule.

Available Monitoring Technologies Could Improve Monitoring at a Small Price

Existing regulations require annual monitoring based on Method 115 – a short-term radon flux test. Although the public asked EPA to analyze and adopt improved monitoring technologies early in the rulemaking, it does not appear that EPA conducted any inquiry into alternative monitoring techniques.

EPA was specificcally alerted to an inexpensive long-term monitoring technology that is is described by Landauer on its website:

> **The RadTrak radon gas detector accommodates the preferred EPA long-term test protocol to account for daily and weekly fluctuations in radon gas levels, contrasting a 2-5 short term test which could yield a false high/low report.** The Radtrak has been used by the US Environmental Protection Agency, US Department of Energy, US Department of Defense, National Institute of Health, American Lung Association, and numerous other public and private organizations and is trusted worldwide.

Exh. 5 (pdf of landauer.com/Radon_Solutions/Industrial_Radon_Monitoring_Service.aspx). On the December 3, 2009 quarterly call, a representative of the regulated industry confirmed that the industry believes that Landauer RadTrak is an example of a viable radon monitoring technology that would only modestly increase industry's monitoring costs:

> It was further discussed that a viable alternative could be the placement of Landauer RadTrak detectors. It was estimated by Oscar Paulson that implementing this alternative would increase costs by 50-100%.

EPA-HQ-OAR-2008-0218-0004. Unfortunately, it does not appear that EPA compared the benefits of requiring improved monitoring technologies with the small increase in monitoring costs described by the industry representative.

As stated above, monitoring based on modern technology must be included in a revised rule.

The Draft Rule Ignores Available Data Sources

The rulemaking is based on an unreasonably narrow review of EPA records, and includes no EPA investigation of conditions on the ground. In discussing exceedances of the 20 pCi/m2-sec limit, the EIA-BID confirms that "[t]wo instances exist in the records that were reviewed" by EPA in promulgating the rule. EIA-BID at 30. These exceedances were identified at both Cotter Mill (2007) and Shootaring Canyon Mill (2009). Seven and five years later, no radon flux monitoring has been reviewed by EPA, even though both mills have open tailings cells and even though each mill is inoperative and/or demolished. There is no indication that EPA followed up at either of these sites to determine actual conditions or to measure current radon flux. Publicly available documents confirm that Cotter's ALARA report included a flux test in August 2012 that resulted in a measured average of 23.3 pCi/m2-sec, contradicting EPA's conclusion that the 2007 exceedances was remedied by throwing some dirt over some of the hot spots. EIA-BID at

30. This information is well known to the community living with the tailings in their airshed, but appears unknow to EPA officials conducting the rulemaking.

Similarly, EPA relies on stale data provided by Denison Corporation, the former owner of the mill near White Mesa. Reliance on Denison-supplied data ignores EPA notices of violation and enforcement actions involving Umetco Minerals Corporation for excessive radon emissions in the early 1990s. EPA Docket No. CAA 113-91-05. The EIA-BID also ignores exceedances of the 20 pCi/m2-sec radon limits and work practices standards in reports submitted to Utah and EPA by Energy Fuels in 2012-2013 that are subject of an ongoing citizen enforcement action. Exh. 1 Amended Complaint, Grand Canyon Trust v. Energy Fuels, Civil Case No.14cv00243 (U.S. Dist. Ct. Utah). The result is a proposed rule based on the misleading and erroneous conclusion that "all values were within regulatory standards" at White Mesa. EIA-BID at 27. EPA review of past and present activities at the mill near White Mesa, many of which are well known in the impacted community, would confirm that the exceedances are recurrent, and that temporary cover results in recurring exceedances. These recurring exceedances support the normal regime of numeric limits, monitoring, and reporting to ensure the predicable spikes in radon emissions do not go undetected and unabated while idle processing wastes linger in private ownership without a permanent radon barrier.

Further, the EIA-BID only discusses the average of the measurements taken across the tailings, and the company-defined regions of the tailings impoundments. Averaging conceals the fact that EPA records confirm radon flux measurements in the 140 pCi/m2-sec range in several regions of existing impoundments. Some of these regions, including the sides and beaches, remain uncovered, resulting in uncontrolled radon emissions for years and sometimes decades. Even with averaging, an undisclosed number of acres at the White Mesa Mill Cell 3 were reported emitting radon at an average flux value of 50.2 pCi/m2-sec. EIA-BID at 31, Table 7.

For cells using phased disposal and water cover, EPA provides no data to confirm whether there are exceedances and recurrent problems with tailings beaches and precipitates associated with water covers. However, the data taken from existing cells compels actual measurement of the effectiveness of phased disposal being used by Energy Fuels at its numerous tailings cells, including Cells 4A and 4A, where radon flux is not being measured and reported pursuant to Subpart W. EIA-BID at 27. The EPA proposal simply ignores the performance of these recently constructed, active cells. EPA inspection and review of the cumulative emissions at the facility near White Mesa would confirm many more than two active impoundments, some of which are larger than 40 acres in size. Similarly, EPA review of existing data and filling data gaps with rulemaking monitoring would confirm the actual amount of radon being emitted from impoundments constructed and put into service after 1989 as compared to post-1989 cells. Perhaps most important, EPA review of the existing UMTRCA licensing documents would confirm that the Part 192 regulations are not being enforced by NRC or Utah, and cannot be used as a basis to avoid EPA CAA regulation. Only after EPA reviews and collects the necessary data and analyzes the regulatory reality can the effectiveness of phased disposal, the current "control technology" being used during operations, be compared against real control technologies such as dry-stack placement, paste tailings, solidification, or any number of available continuous cover technologies. By contrast, no tailings-handling and placement technology that avoids open air storage and water cover is even mentioned in the EIA-BID. The EIA-BID does not consider the

lack of approved closure plans at the White Mesa and Cotter facilities, but bases the proposed rule on the false assumption that closure plans exist and are being implemented expeditiously.

The data provided for the Sweetwater Mill is somewhat more comprehensive, and confirms that radon emissions vary widely over time. In order for EPA to reach a reasoned decision, this type of information, from 1989 to the present, must be made available from all sites, analyzed, and confirmed by EPA site visits and third-party radon flux measurement.

The Sweetwater data reveals, but does not analyze or explain, an achievable reduction from 9 pCi/m2-sec reported in 1990 to 1.44 pCi/m2-sec reported for 2010. EIA-BID at 24. These variations and reductions provide the basis of a numeric limit no greater than 10 pCi/m2-sec, and likely lower where modern technologies are deployed. According to Kennecott, "The twenty (20) year average for the impoundment as a whole is 4.65 pCi/M2-sec. The average for the exposed tailings is 8.69 pCi/m2-sec." Kennecott's Subpart W Comments dated April 25, 2012 at 5.

Despite the reduced radon emissions, the Sweetwater mill provides another example of the indefinite storage of uranium wastes without permanent radon barrier. Sweetwater is the current example confirming an industry practice of leaving inactive the tailings cells unclosed, sometimes for decades, claiming a vague intent to restart operations. Cotter made the same types of claims until it demolished its milling facilities in 2011, then dumped them into tailings impoundments that still lack an approved closure plans with enforceable milestones. The proposed rule is based on the erroneous premise that Cotter has plans use the impoundments for heap leaching. EIA-BID at 38. Cotter has requested that Colorado terminate Cotter's UMTRCA license, even though no closure plan has been approved for the existing impoundment. Exh. 6 CCAT Comments on Superfund and License Actions at 2. Where radon NESHAP Parts W and T have proved ineffective at preventing indefinitely open tailings cells, and NRC and Agreement States do not require Part 192 closure plans that achieve permanent radon cover within a reasonable time, a comprehensive rewrite of these NESHAPs is required. This is particularly true where the proposed rule is based on demonstrably inaccurate information.

In Situ Leaching of Uranium From Aquifer-Covered Orebodies

These comments support the NESHAP regulation of radon from all uranium processing wastes, including all solid and liquid wastes created and stored at in situ uranium leach ("ISL") facilities. The data collected by EPA supports emissions limits and monitoring to ensure available control technologies are deployed. Industry representatives' claims of being able to achieve and maintain zero radon emissions from evaporation cells should be used as a basis to set a very low radon flux limit for ISL facilities, somewhere in the range of 1 to 2 pCi/m2-sec or at measured, pre-ISL background levels.

However, industry's horatory claims of zero emissions are contradicted by Kennecott's explanation of high radon background readings at its Sweetwater facility. Kennecott claims that its background radon is elevated where water bodies 9-10 miles upwind contain high radium-226 and associated evaporites that contributes a significant source of radon emission.

> These long term elevated background radon concentrations in ambient air are probably due to the presence of a series of playa lakes in an area known as Battle Spring Flat approximately nine (9) to ten (10) miles southwest (upwind) of the facility. This area and its relationship to the facility are shown on the image provided in Appendix 20. This area contains numerous springs and seeps of groundwater that create shallow playa lakes with associated deposits of salts left behind by evaporation of the groundwater. These salts contain among other elements Radium-226 which are a Radon-222 source. The water in these playa lakes (depending on the level of evaporation) can have high concentrations of Radium-226. The August 28, 1975 sample of Hansen Lake had a Radium-226 activity of 33.6 picoCuries per liter. (Annual Report – Permit to Mine #481 – October 27, 2004).

Kennecott's Subpart W Comments dated April 25, 2012 at 13. Kennecott's concern about the upwind playa lakes highlight the important role of radium-226 in radon emissions from evaporation ponds at existing conventional and ISL facilities.

EPA has sufficient authority and information to confirm the need to regulate radon emissions from solid and liquid wastes at all uranium processing facilities as NESHAPs, including ISL facilities. However, EPA has not gathered the necessary information to determine the proper standard based on what is achievable by available ISL technologies or at what cost.

Open Air Heap Leach

Open air leaching of uranium poses an unacceptable risk, whether conducted via acid or alkali leaching. These comments support a new rule for heap leaching that sets numeric emissions based on available technologies such as a physical enclosure during the leaching process. Although heap leach has been used in the U.S. and is being used internationally, EPA provides no data from the files kept by any company or regulatory body that confirms the groundwater contamination and emissions from such sites. As with conventional mills, such data will confirm that NESHAP regulation must include numeric emissions limits and enforceable monitoring and reporting requirements.

Conclusion

EPA has failed to provide a radon NEPSHAP regulation for uranium processing facilities that embraces the numeric standards, enforceability, and technology-forcing components of the Clean Air Act.

These comments request that EPA prepare a new draft, without further delay, that respects principles of Environmental Justice, Clean Air Act mandates, and the on-the-ground failures of the current work practice standards. These and other impacted communities remain willing to work closely with EPA to achieve these ends, given the opportunity and resources required to carry out EPA's Environmental Justice policies.

Respectfully Submitted,
s/Travis E. Stills
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UNITED STATES DISTRICT COURT
DISTRICT OF UTAH
CENTRAL DIVISION

GRAND CANYON TRUST, Plaintiff, vs. ENERGY FUELS INC.; ENERGY FUELS HOLDING CORP; EFR WHITE MESA LLC.; & ENERGY FUELS RESOURCES (USA) INC., Defendants.	Case No. 14-cv-00243-DBP **FIRST AMENDED COMPLAINT FOR DECLARATORY RELIEF, INJUNCTIVE RELIEF, AND CIVIL PENALTIES**

INTRODUCTION

1. Plaintiff Grand Canyon Trust (Trust) brings this lawsuit to enforce violations of the Clean Air Act (CAA), 42 U.S.C. § 7412, against Energy Fuels Inc., Energy Fuels Holding Corp., EFR White Mesa LLC, and Energy Fuels Resources (USA) Inc. (collectively referred to hereinafter as Energy Fuels) at the White Mesa Uranium Mill. The White Mesa Mill is releasing Radon-222, a cancer-causing gas emitted from the radioactive wastes generated from uranium milling and a CAA-designated hazardous air pollutant. White Mesa Mill's tailings impoundments, which store these milling wastes, are not conforming to mandatory CAA emissions limits, work practice standards, and monitoring, reporting and notification requirements. 40 C.F.R. §§ 61.250 et seq. (Subpart W). These regulatory requirements are designed to curtail releases of Radon-222 and ensure the timely reclamation of a mill's impoundments. Id. Section 112 of the CAA prohibits Energy Fuels from operating White Mesa Mill and emitting Radon-222 in violation of these limits, standards, and requirements. 42 U.S.C. § 7412(f)(4), § 7412(i)(3)(A). Consequently, in accordance with the CAA citizen suit provision, 42 U.S.C. § 7604(a), the Trust seeks relief that enforces the CAA emissions standards and limits and assesses civil penalties against Energy Fuels for these violations of law. Energy Fuels' CAA violations pose a serious and continuing threat to nearby communities, the region's people, and the environment that can be remedied by the statutory relief sought in this complaint. *See e.g.* 42 U.S.C. §§7604 (a), (d-e) & (g).

JURISDICTION AND VENUE

2. This Court has jurisdiction over this action under 42 U.S.C. § 7604(a)(1) (CAA citizen suit provision). Pursuant to 42 U.S.C. § 7604(b), Plaintiff provided Energy Fuels with sixty-day notices of intent to sue on January 29, 2014 and July 29, 2014 for CAA violations at

White Mesa Mill prior to filing this amended complaint. Notice was also provided to the U.S. Environmental Protection Agency (EPA) and the State of Utah. Neither the EPA nor the State of Utah has commenced and is diligently prosecuting a civil action in court to enforce the CAA violations that Plaintiff is alleging.

3. Venue is proper in the District Court for the District of Utah pursuant to 42 U.S.C. § 7604(c) and 28 U.S.C. § 1331.

PARTIES

4. Plaintiff Grand Canyon Trust is a non-profit corporation with offices in Moab, Utah, Durango and Denver, Colorado and headquarters in Flagstaff, Arizona. The Trust has approximately 4,000 members, including those who reside, work, visit, and recreate in Utah and Colorado. The mission of the Trust is to protect and restore the Colorado Plateau – its spectacular landscapes, flowing rivers, clean air, diversity of plants and animals, and areas of beauty and solitude. One of the Trust's goals is to ensure that the Colorado Plateau's air is safe for the region's people and visitors, its water resources are free of contaminants for people and wildlife, and that sources emitting air pollutants comply with federal and state laws. The Trust works to ensure that the Colorado Plateau's resources are used responsibly to sustain the livelihood of present and future generations.

5. Trust members enjoy the air, lands, and waters adjacent to, nearby, and downwind of the White Mesa Mill. Trust members live, work, visit and recreate within the area most impacted by the White Mesa Mill's radon emissions, including White Mesa, Blanding, and Bluff, Utah. Trust members regularly use the private and public lands adjacent to and near White Mesa Mill to pursue their interests -- including hunting, hiking, plant-gathering, camping, water activities, and photographing wildlife and scenery -- scientific study and educational

activities. Trust members derive recreational, inspirational, religious, scientific, educational, and aesthetic benefits from their regular use and activities in the area near White Mesa Mill. Trust members obtain drinking water from groundwater in the region. Trust members hunt and consume wildlife taken from areas near the White Mesa Mill. Trust members continue to enjoy their lives and pursue their interests, including the aforementioned activities in the areas of White Mesa Mill. Trust members' use and enjoyment of the areas near White Mesa Mill is greatly enhanced by clean air that is free of hazardous air pollutants, by surface and groundwater that is free of contaminants associated with uranium tailings impoundments, and by tailings impoundments that are fully and promptly closed and reclaimed by the Mill operator. Trust members are exposed to White Mesa Mill's radon emissions at various times of the year. Trust members are exposed to contaminants, including Radon-222, released from White Mesa Mill's tailings impoundments into surface and groundwater. The Trust and its members are persons within the meaning of § 304(a) of the Clean Air Act. 42 U.S.C. § 7604 (a).

6. Violation of the CAA's radon emission limits, work practice standards, and reporting, monitoring and notification requirements at White Mesa Mill harm and injure Trust members, including their health, their use and enjoyment of the air, land and waters in the region, their interest in the protection of wildlife, native plants, clean air and water, and their interest in having businesses and regulated entities operating in the region adhere to laws and regulations. These injuries occur because Energy Fuels has operated and continues to operate White Mesa Mill in violation of the CAA. Despite repeated violations, neither Utah nor the EPA has imposed civil penalties to bring the White Mesa Mill into compliance with the CAA. Energy Fuels' CAA violations increase the likelihood that reclamation activities at White Mesa Mill will not occur, will be delayed, or will result in the public having to pay for cleanup and reclamation activities.

7. The CAA's citizen suit provision authorizes the Trust to bring this action as "private attorney general." A court order providing declaratory and injunctive relief, enforcing the CAA standards and limits, imposing civil penalties against Energy Fuels, and requiring Energy Fuels to fund a supplemental environmental project will redress the Trust's injuries resulting from Energy Fuels' violations of the CAA at the White Mesa Mill.

8. Defendant Energy Fuels Inc. owns and/or operates the White Mesa Mill. Energy Fuels Inc.'s principal place of business and corporate office is located at 225 Union Blvd., Suite 600, Lakewood, Colorado 80228, USA. Energy Fuels Inc.'s website address is www.energyfuels.com. As of June 30, 2014, Energy Fuels Inc. had a working capital of $42.26 million. Energy Fuels Inc. has control of each Defendant named in this complaint. On information and belief, Defendants jointly hold complete ownership and operational control of the White Mesa Mill.

9. Energy Fuels Inc. conducts its business through a number of subsidiaries. Many of Energy Fuels Inc.'s U.S. assets, including the White Mesa Mill, are held through the Energy Fuels Inc.'s wholly- owned subsidiary Energy Fuels Holdings Corp. Energy Fuels Holdings Corp. owns and/or operates the White Mesa Mill. EFR White Mesa LLC is a wholly owned subsidiary of Energy Fuels Inc. and Energy Fuels Holdings Corp. EFR White Mesa LLC owns and/or operates the White Mesa Mill. Energy Fuels Resources (USA) Inc. is a wholly owned subsidiary of Energy Fuels Inc. and Energy Fuels Holding Corp. Energy Fuels Resources (USA) Inc. owns and/or operates the White Mesa Mill. Based on Energy Fuels Inc.'s financial statements and regulatory filings, Energy Fuels Inc. owns 100% interest in Energy Fuels Holdings Corp., EFR White Mesa LLC, and Energy Fuels Resources (USA) Inc. Based on Energy Fuels Inc.'s webpage and filings with the respective Secretary of State offices, Energy

Fuels Inc., Energy Fuels Holdings Corp. EFR White Mesa LLC, and Energy Fuels Resources (USA) Inc. share the same corporate officers. Energy Fuels Inc., Energy Fuels Holdings Corp. EFR White Mesa LLC, and Energy Fuels Resources (USA) Inc. are represented by the law firm of Parsons, Behle & Latimer. Based on Energy Fuels Inc.'s financial statements and regulatory filings, Energy Fuels Inc., Energy Fuels Holdings Corp. EFR White Mesa LLC, and Energy Fuels Resources (USA) Inc. file consolidated financial statements. Based on Energy Fuels Inc.'s financial statements and regulatory filings in which company history is described, Energy Fuels Inc. caused the incorporation of Energy Fuels Holdings Corp, EFR White Mesa LLC, and Energy Fuels Resources (USA) Inc. Based on Energy Fuels Inc.'s webpage, financial statements, and regulatory filings, Energy Fuels Inc. refers to the White Mesa Mill property as its own and uses the White Mesa Mill property as its own. In April 2014, during the first 60-day notice period, the Trust discussed the notice with corporate officers of Energy Fuels Inc. Based on each corporations' filings with the Secretary of State, these individuals are also corporate officers of Energy Fuels Resources (USA) Inc., Energy Fuels Holding Corp., and EFR White Mesa LLC. Based on publically available documents, the principals and officers of Energy Fuels Holding Corp. and Energy Fuels Inc. comment and participate in correspondence related to environmental regulations applicable to the White Mesa Mill, participate in meetings related to environmental compliance at the White Mesa Mill, and are points of contact regarding compliance with environmental laws at the White Mesa Mill. These representatives exert direct control over White Mesa Mill operations on behalf of each named defendant. Based on each corporations' filings with the respective Secretaries of State offices and Energy Fuels Inc.'s webpage, each named defendant shares the same corporate headquarters in Lakewood, Colorado. Each named Defendant is a "person" within the meaning of Section 302 of the CAA. 42 U.S.C.

§ 7602(e).

STATUTORY BACKGROUND - CLEAN AIR ACT

10. The Clean Air Act regulates the release of hazardous air pollutants. 42 U.S.C. § 7412. Hazardous air pollutants threaten "adverse human health effects … or adverse environmental effects." Id. at § 7412(b)(2). Radon is identified as a hazardous air pollutant under the CAA. Id. § 7412(b) (identifying radionuclides, including radon, as hazardous air pollutant); see 44 Fed. Reg. 21,704 (April 11, 1979) (EPA's listing of radionuclides as hazardous air pollutant).

11. Radon-222 is a cancer-causing radioactive gas that poses a serious health hazard. According to EPA, there is no safe level of radon, as any exposure poses some risk of cancer. Radon-222 is the second leading cause of lung cancer in the United States, resulting in 21,000 deaths annually. In addition, exposure to Radon-222 is linked to genetic defects, and increases in mortality as well as serious irreversible illnesses.

12. Radon-222 is associated with uranium mills. The process of separating uranium from its ore -- milling -- creates a waste material known as "tailings." Because uranium ore generally contains less than 1 percent uranium, uranium milling produces large amounts of tailings. Tailings are collected at mill sites in impoundments that vary in size. Uranium tailings contain significant amounts of radium. Consequently, tailings impoundments are a significant source of Radon-222 emissions until a permanent radon barrier is completed. A dry tailings impoundment releases more Radon-222 into the air than saturated or liquid tailings. The side regions of tailings impoundments are drier, and emit more Radon-222 into the air than water covered regions. Water can reduce Radon-222 emissions from tailings. Water does not

eliminate the release of Radon-222 from tailings. Using water to control Radon-222 emissions poses a threat of groundwater contamination.

13. Radon-222 atoms emitted from these tailings impoundments attach to airborne dust particles and can travel many miles in this form before decaying. People downwind of tailings impoundments are exposed to Radon-222. When radioactive dust is inhaled, the dust will stick to lungs where radon and its progeny decay and irradiate the lungs' fluids and tissues, and increase the risk of lung cancer. Short-lived radon progeny decay after several days and emit the alpha radiation that is a significant contribution to radiation dose in most practical radon exposure situations. Proximity to impoundments influences cancer rates, and EPA has found that "the relatively few people who live within a few kilometers of tailings piles may receive individual exposures as much as a hundred times the exposures to individuals at greater distances."

14. CAA Section 112 prohibits owners and operators of stationary sources from emitting hazardous air pollutants, including radon, or operating a stationary source in violation of applicable limitations and standards. 42 U.S.C. § 7412(f)(4) ("No air pollutant to which a standard under this subsection applies may be emitted from any stationary source in violation of such standard"); id. at § 7412(i)(3)(A) ("…no person may operate such source in violation of such standard, limitation or regulation…"). A stationary source is defined as "any building, structure, facility, or installation which emits or may emit any air pollutant." Id. at § 7412 (a)(3) Violations of these prohibitions are enforceable through the CAA's citizen suit provision. Id. at § 7604(a)(1). This provision authorizes suits "against any person … who is alleged to have violated or to be in violation of (A) an emission standard or limitation under this chapter…" Id. As defined, an "emission standard or limitation" includes the requirements set forth under 42

U.S.C. § 7412 without regard to whether such requirement is expressed as an emission standard or otherwise, and "any permit term or condition." 42 U.S.C. § 7604(f)(3) & (4).

15. The standards and limits governing sources of hazardous air pollutants are found in the CAA's regulations. In 1989, EPA promulgated regulations to control the emissions of radionuclides from various sources. 54 Fed. Reg. 51,703 (Dec. 15, 1989). Subpart W of these regulations -- found at 40 C.F.R. §§ 61.250 et seq. -- applies specifically to Radon-222 emissions from tailings impoundments at uranium mills and establishes the relevant limits and standards. 40 C.F.R. § 61.250 (defining uranium mills as those facilities "licensed to manage uranium byproduct materials during and following the processing of uranium ores."); 40 C.F.R. § 61.252 (setting forth emission limits and work practice standards). The Subpart W regulations require compliance with ground water protection standards set forth in 40 C.F.R. 192.32(a)(2). 40 C.F.R. § 61.252(c) ("All mill owners or operators shall comply with the provisions of 40 CFR 192.32(a)."). Tailings -- referenced in these regulations as "uranium byproduct material" -- are defined as "wastes produced by the extraction or concentration of uranium from any ore processed primarily for its source material content." 40 C.F.R. § 61.251(g).

16. One of the Subpart W standards is a numeric emissions limit. Radon-222 emissions from an existing uranium tailings pile shall not exceed 20 picocuries per square meter per second (pCi/m^2-sec). 40 C.F.R. § 61.252(a). Under applicable regulations, the operator may choose to measure emissions once-a-year, or at weekly, monthly or quarterly intervals. If weekly, monthly or quarterly measurements of emissions are used, radon emissions for each measurement period are averaged. Compliance with this emission limit is determined annually, based on the calendar year. 40 C.F.R. § 61.253.

17. Compliance with this emission limit is calculated according to the protocols set forth in "Method 115." 40 C.F.R. § 61.253. Method 115 prescribes the required frequency and location of an operator's radon flux measurements at an existing uranium mill tailings pile. 54 Fed. Reg. at 51,709 (Dec. 15, 1989). For each measurement period, Method 115 requires operators to take 100 radon flux measurements from three distinct regions of the existing impoundment: the water saturated areas (the "beaches"), the dry top surface areas, and the sides. The weather conditions at the time of each radon flux measurement event shall be chosen to provide measurements indicative of the long-term radon flux from the pile. Id. Under Method 115, a mill operator must report any condition or unusual event that occurred during the measurements that could significantly affect the results. Id.

18. Subpart W also contains notification and reporting requirements. Mill operators must provide EPA with a schedule of the measurement frequency for radon flux measurement events from existing tailings impoundments. 40 C.F.R. § 61.253. The mill operator may submit a schedule to EPA before or after the first measurement period. Id. Mills must report the results of the radon flux measurements conducted pursuant to Method 115, by March 31st of the following calendar year. Id. at § 61.254(a). If the 20 pCi/m^2-sec emission limit is violated, the mill must measure emissions at monthly intervals and file monthly reports with the EPA. Id. at § 61.254(b).

19. Subpart W also contains "work practice" standards that govern tailings impoundments constructed after December 15, 1989. 40 C.F.R. § 61.252(b). EPA adopted these work practice standards to overcome the problem of mills operating multiple, large tailings impoundments that emit significant amounts of Radon-222. 54 Fed. Reg. at 51,679 (Dec. 15, 1989). One purpose of the work practice standards is reduce Radon-222 emissions and protect

groundwater by requiring timely closure of tailings cells that have been filed to capacity. These standards address the fact that, at many mill sites, tailings impoundments have been abandoned by the mill operator and were not closed and reclaimed. For example, the ongoing cost of the federal closure and remediation of approximately sixteen million tons of uranium tailings at the Atlas Minerals Corporation site outside Moab, Utah is expected to exceed $1 billion.

20. These work practice standards vary depending on the mill's process for "disposal" -- or closure -- of impoundments: "phased" or "continuous" disposal. The disposal of a tailings impoundment occurs after the impoundment can no longer be used, and requires compliance with the closure procedures set forth in 40 C.F.R. § 192.32. "Phased disposal" means "us[ing] lined impoundments which are filled and then immediately dried and covered to meet all applicable Federal standards." 40 C.F.R. § 61.251(f). For tailings managed according to a phased disposal process, the work practice standards limit the number and size of tailings impoundments. Id. at § 61.252(b)(1).

21. For owners and operators managing tailings according to phased disposal, the construction and operation of new (after December 15, 1989) impoundments is prohibited if the owner or operator of the mill is operating more than two tailings impoundments. 40 C.F.R. § 61.252(b)(1). An operating impoundment is one "being used for the continued placement of new tailings or is in standby status for such placement. An impoundment is in operation from the day that tailings are first placed in the impoundment until the day that final closure begins." Id. at § 61.251(e).

22. Interim closure begins when the impoundment is no longer used for placement of new tailings and involves decommissioning activities such as dewatering the tailings and placement of an interim radon barrier. 40 C.F.R. § 192.32(a)(3).

23. Final closure begins with the installment of a permanent radon barrier designed to prevent or limit the release of Radon-222 for centuries. 40 C.F.R. § 192.32(a)(4)(i). Tailings impoundments in final closure are subject to regulation pursuant to the requirements set forth in 10 C.F.R. Part 40, Appendix A, and 40 C.F.R. Part 192 Subpart D. Final closure involves placement of several layers of clay, rock and other materials to create an engineered cap designed to limit Radon-222 release and to protect groundwater by preventing infiltration of water into the tailings. Id. The permanent radon barrier must be emplaced in accordance with a written tailings closure plan that complies with UMTRCA timing requirements and closure standards that is incorporated into the Mill's license by a license amendment. A tailings closure plan must contain key radon closure milestone activities such as wind blown tailings retrieval and placement in the impoundment, , and emplacement of the various components of the permanent radon barrier. 40 C.F.R. § 192.31(n); 10 C.F.R. Part 40 Appendix A Criterion 6(A)(1)

24. Tailings impoundments in final closure were subject to CAA regulation pursuant to CAA NESHAP Subpart T, which implemented the 20 pCi/m^2 radon emission standard during closure. 40 C.F.R. § 61.220 et seq. Subpart T was rescinded on June 29, 1994 based on the premise that Clean Air Act standards in 42 U.S.C. 7412(i)(3) and the numerical 20 pCi/m^2 standard would be met where impoundments are promptly closed by placing a permanent radon barrier in accordance with enforceable milestones and no more than seven years after the first day of final closure 59 Fed Reg. 36282-83 (July 15, 1994).

25. Final closure is complete with testing of the permanent radon barrier to ensure effectiveness over a period of centuries and transfer of the impoundment to a government agency for perpetual care. 40 C.F.R. § 192.32(b). During perpetual care of tailings impoundments

involving UMTRCA Title II sites, the 20 pCi/m^2 standard used throughout CAA NESHAP regulations remains applicable to radon emissions from uranium tailings. 40 C.F.R Subpart Q, Id. at § 61.192 ("No source at a Department of Energy facility shall emit more than 20 picocuries per square meter per second (pCi/(m2-sec)) (1.9 pCi/(ft2-sec)) of radon- 222 as an average for the entire source, into the air.").

26. Where tailings are managed according to the phased disposal work practice standard, a new impoundment cannot exceed 40 acres in size. 40 C.F.R. § 61.252(b)(1). This size limitation is designed to limit radon emissions to the 20 pCi/m^2 radon emission standard and protect groundwater by ensuring timely and efficient reclamation and closure. 51 Fed. Reg. 34,055, 34,062 (Sept. 24, 1986).

FACTUAL ALLEGATIONS GIVING RISE TO THE CLAIMS

27. White Mesa Mill processes conventional uranium ore that is mined on the Colorado Plateau. Currently, the White Mesa Mill is the only conventional uranium mill operating in the United States. Most of the licensed uranium mills in the United States were closed in the early 1980s and decommissioned under provisions of Title I of the Uranium Mill Tailings Radiation Control Act amendments to the Atomic Energy Act. The White Mesa Mill is located in San Juan County, Utah, less than five miles from the White Mesa community populated by members of the Ute Mountain Ute tribe, less than ten miles from Blanding, Utah, and less than thirty miles from Bluff, Utah.

28. Construction of the White Mesa Mill began in 1979, and operations commenced in May 1980. Between 1980 and 2008, White Mesa Mill operated at various levels of capacity, but processed 4.5 million tons of uranium ore. The Mill has been fully operational since 2008. Since at least April 2008, the Mill has operated periodically, with significant idle periods.

Energy Fuels plans to place the White Mesa Mill on standby in the second half of fiscal year of 2014 by discontinuing processing while continuing to receive and stockpile uranium ore and alternate feed. Energy Fuels plans to continue operations on a campaign basis, which means intermittent periods of active milling as well as periods of stockpiling feedstock with no active milling During standby, the tailings impoundments continue to emit Radon-222.

29. Ownership of White Mesa Mill has changed over time. The Mill was built by a company known as Energy Fuels Nuclear. In 1984, Energy Fuels Nuclear sold the White Mesa Mill to Umetco Minerals, an affiliate of Union Carbide. Umetco operated White Mesa Mill until 1994, when it was sold back to Energy Fuels Nuclear. Shortly thereafter, Energy Fuels Nuclear went bankrupt and ceased operating White Mesa Mill in 1995. In 1997, International Uranium Corporation purchased the White Mesa Mill. In 2006, International Uranium Corporation changed its name to Denison Mines as a result of a corporate merger. In 2012, Energy Fuels Inc. assumed ownership of Denison Mines' U.S. assets, including the White Mesa Mill.

30. Beginning in 1987, White Mesa Mill began accepting "alternate feed" for processing, supplementing the amount of uranium ore being milled. Whereas a conventional mill operator typically pays for uranium ore feedstock, a mill owner is paid to accept and dispose of uranium-bearing "alternate feeds." Alternate feed is another name for radioactive wastes that contain small amounts of uranium-bearing materials. By processing these radioactive wastes as alternate feed, White Mesa Mill provides hazardous waste sites across the country a means to dispose these wastes without being subject to various federal and state laws (such as, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)), and without having to undertake removal and remediation actions. The Environmental Protection Agency has recognized that this practice has potential for abuse where lower disposal fees at

economically marginal uranium mills can result in "sham processing" to convert CERCLA wastes into non-CERCLA mill tailings. Utah regulators have expressed concern that less stringent, cheaper, non-CERCLA disposal of radioactive wastes at uranium mills pose problems, particularly where the technical and economic viability of uranium recovery is doubtful.

31. In 1995, EPA delegated authority to the State of Utah to regulate emissions of radon and implement 40 C.F.R § 61.250 et seq. On March 2, 2011, the State of Utah issued Denison a modified "minor source" air quality permit for White Mesa Mill. The Mill's 2011 permit requires compliance with the regulatory requirements set forth in 40 C.F.R. § 61.250 et seq.

32. Energy Fuels possesses two other permits applicable to White Mesa Mill issued by agencies with the Utah Department of Environmental Quality ("DEQ") pursuant to Utah statutes and regulations - a Groundwater Discharge Permit ("GWDP") and a Radioactive Materials License. Neither permit governs radon emissions from the Mill's tailings impoundments. Neither permit exempts Energy Fuels from compliance with federal law. During 2011, 2012, and 2013, the White Mesa Mill reported consecutive exceedances of groundwater compliance limits under the White Mesa Mill's GWDP for several constituents in several wells. Instead of issuing fines or requiring compliance, Utah DEQ has changed the groundwater standards. Utah DEQ is aware of repeated and ongoing Subpart W violations, but has not taken action to enforce the standards. Neither Utah DEQ nor the U.S. Environmental Protection Agency have levied civil penalties to deter future violations of Subpart W.

33. White Mesa Mill is a source of air pollution. There are six tailings impoundments at White Mesa Mill, which Energy Fuels refers to as Cell 1, Cell 2, Cell 3, Cell 4A, Cell 4B and Roberts Pond. Energy Fuels operates each of these tailings impoundments on a "phased

disposal" basis. Construction of Cell 1 was completed in June 1981. Construction of Cell 2 was completed in May 1980. Construction of Cell 3 was completed in September 1982. On information and belief, earthen materials were not used in the dam construction for Cell 3.

34. Cells 4A and Cell 4B were constructed after December 15, 1989. Cell 4 was divided into 4A and 4B to avoid the regulatory restriction on the size of a tailings impoundment. Cell 4A exceeds the 40-acre limit on the size of a tailings impoundment. Cell 4B exceeds the 40-acre limit on the size of a tailings impoundment. Cell 4B was constructed in 2010. In 2010, White Mesa Mill was licensed to dispose tailings into Cell 4B.

35. Energy Fuels has disposed of waste produced by milling uranium ore in Cells 1, 2, 3, 4A, 4B, and Roberts Pond. Energy Fuels has disposed of and disposes of mill laboratory waste, fluid from the Mill process (raffinate), and stormwater runoff in Cell 1. Cell 2 was licensed to receive uranium byproduct materials by the Mill's groundwater discharge permit and radioactive materials license in 2012 and 2013. Cell 3 is an existing impoundment as defined in 40 C.F.R. § 61.251(d). Cell 3 receives slime drain fluid from Cell 2, solid Mill waste, and solid uranium byproduct material from in-situ recovery facilities. Cell 4A receives solutions from the Mill process (raffinate) and solid mill waste. Cell 4B receives fluid from mill process (raffinate). Nothing in the Mill's license or groundwater discharger permit restricts Cell 4B from receiving solid Mill waste. Cell 4B was designed to receive solid Mill waste. Cells 1, 3, 4A, and 4B are licensed to receive uranium byproduct material by the Mill's groundwater discharge permit and radioactive materials license. Roberts Pond receives waste produced by the extraction or concentration of uranium from ore processed primarily for its source material content. In 2002, Energy Fuels relined Roberts Pond because the build up of solids in the pond from over 20 years of operation had reduced pond capacity to unacceptable levels. Roberts Pond receives process

spills and overflows from Mill operations. All cells use evaporation to reduce the volume of solid and liquid waste produced by the extraction or concentration of uranium from ore processed primarily for its source material content.

36. Processing wastes at the Mill facility that are not regulated as 11(e)(2) byproduct materials are subject to regulation as hazardous waste pursuant to the Resource Conservation and Recovery Act ("RCRA"). Defendants do not have any RCRA permits for the wastes placed in any cell at the White Mesa Mill.

37. Energy Fuels measures Radon-222 emissions from Cell 2 and Cell 3 using the measurement protocol set forth in Method 115. Energy Fuels employs Large Area Activated Charcoal Cannisters, which are passive gas absorption sampling devises that determine the flux rate of Radon-222 gas from the surface of tailings impoundments.

FIRST CLAIM FOR RELIEF
(Violation of the Clean Air Act and implementing regulations, Radon-222 Emission Limit, 40 C.F.R. § 61.252(a))

38. Each and every allegation set forth in this Complaint is incorporated herein by reference.

39. Radon-222 emissions from an existing tailings impoundment "shall not exceed 20 pCi/m^2-sec." 40 C.F.R. § 61.252(a). Compliance with this emission limit is determined annually. Id. at § 61.253.

40. White Mesa Mill's Cell 2 was in existence on December 15, 1989. Since 1992, Energy Fuels has been measuring Radon-222 emissions from Cell 2 once-a-year. From 2001 to 2012, Energy Fuels conducted its once-a-year measurement in June.

41. In 2012, Energy Fuels' operations at White Mesa Mill violated the Radon-222 emission limit. Energy Fuels' June 2012 measurements revealed an exceedance of the 20

pCi/m^2-sec emissions limit. Energy Fuels reported that Radon-222 emissions from Cell 2 in June 2012 were 23.10 pCi/m^2-sec. Based on this report, Energy Fuels violated the emissions limit in 2012.

42. This 2012 violation was reaffirmed by additional measurements. After the June 2012 violation, Energy Fuels increased the frequency of Radon-222 measurements at Cell 2. When the measurement frequency is more than once-per-year, each measurement event is averaged over the course of the year. Energy Fuels measured emissions from Cell 2 in September, October and November of 2012, in addition to June 2012. Emissions from Cell 2 in September 2012 were 26.60 pCi/m^2-sec. Emissions from Cell 2 in October 2012 were 27.70 pCi/m^2-sec. Emissions from Cell 2 in November 2012 were 26.10 pCi/m^2-sec. Energy Fuels calculated the Mill's 2012 annual emission rate of 25.90 pCi/m^2-sec by averaging the readings from the four 2012 monitoring events. In March 2013, Energy Fuels reported that it violated the emissions limit for Radon-222 in 2012 at Cell 2 at the White Mesa Mill.

43. In 2013, Energy Fuels' operations at White Mesa Mill violated the Radon-222 emission limit. Monthly measurements of Radon-222 emissions at Cell 2 began in April 2013 after the 2012 violation was reported in March 2013. Nine monthly reports were filed in 2013. The arithmetic mean of the nine 2013 monitoring events from April to December of 2013 from Cell 2 is 20.42 pCi/m^2-sec. In March 2014, Energy Fuels reported that it violated the emissions limit for Radon-222 in 2013 at Cell 2 at the White Mesa Mill.

44. At the White Mesa Mill's Cell 2, Energy Fuels has violated and is violating its air permit and the CAA's emission limit for Radon-222. See 40 C.F.R. §§ 61.252(a), 61.253. These violations of the CAA -- 42 U.S.C. § 7412(f)(4) and § 7412(i)(3)(A) -- are enforceable under the CAA citizen suit provision.

SECOND CLAIM FOR RELIEF
(Violation of the Clean Air Act and implementing regulations, Number of Tailings Impoundments, 40 C.F.R. § 61.252(b)(1))

45. Each and every allegation set forth in this Complaint is incorporated herein by reference.

46. After December 15, 1989, a uranium mill utilizing phased disposal is prohibited from either constructing or operating more than two tailings impoundments. 40 C.F.R. § 61.252(b)(1). This work practice standard is an emission standard, limitation, or regulation under the CAA.

47. White Mesa Mill's Cell 4B was constructed in 2010. At the time Cell 4B was constructed, White Mesa Mill had more than two tailings impoundments in operation. Cell 4B was constructed while Cell 1 was operating. Cell 4B was constructed while Cell 2 was operating. Cell 4B was constructed while Cell 3 was operating. Cell 4B was constructed while Roberts Pond was operating. Cell 4B was constructed while Cell 4A was operating.

48. Cell 4B is an operating tailings impoundment. There continue to be more than two tailings impoundments in operation at White Mesa Mill. Cell 1 is in operation at White Mesa Mill. Cell 2 is in operation at White Mesa Mill. Cell 3 is in operation at White Mesa Mill. Cell 4A is in operation at White Mesa Mill. Cell 4B is in operation at White Mesa Mill. Roberts Pond is in operation at White Mesa Mill. Initial closure and reclamation measures, such as dewatering the tailings and placing interim radon barriers, have begun at Cell 2. No other cells are undergoing reclamation or interim closure. No tailings impoundment at White Mesa Mill has begun final closure. No tailings impoundment at White Mesa Mill has been covered in a manner shown to effectively control radon for at least two hundred years. Energy Fuels has not placed a

final radon barrier on Cell 1, Cell 2, Cell 3, Cell 4A, Cell 4B, or Roberts Pond. The State of Utah Division of Radiation Control has not incorporated a written tailings closure plan for any cell or Roberts Pond into the Radioactive Materials License for the White Mesa Mill. Subpart T of the CAA regulations governing hazardous air pollutants does not apply to any tailings impoundment at the White Mesa Mill.

49. By exceeding the regulatory limit on the number of tailings impoundment at White Mesa Mill, Energy Fuels has violated and continues to violate the CAA's work practice standard. See 40 C.F.R. § 61.252(b)(1); 42 U.S.C. § 7412(f)(4) and § 7412(i)(3)(A). Energy Fuels' violations of the CAA -- 42 U.S.C. § 7412(f)(4) and § 7412(i)(3)(A) -- are enforceable under the CAA citizen suit provision.

THIRD CLAIM FOR RELIEF
(Violation of the Clean Air Act and implementing regulations, Notification Requirements, 40 C.F.R. § 61.253

50. Each and every allegation set forth in this Complaint is incorporated herein by reference.

51. The owner or operator of a uranium mill must provide EPA with a schedule that details the measurement frequency for radon emissions at the mill's existing impoundment for the purpose of determining compliance with the CAA's radon emission limit at 40 C.F.R. 61.252(a). The operator may submit the measurement schedule prior to or after the first measurement period.

52. On April 11, 2013, Energy Fuels submitted a measurement schedule for radon flux measurements for Cell 3. In the April 11, 2013 letter, Energy Fuels stated that it planned to perform an annual sampling event between June 10 and June 13, 2013.

53. The results of Energy Fuels' June sampling of Cell 3 revealed that emissions from

Cell 3 were 22.7 pCi/m^2-sec. Emissions from Cell 3 in June 2013 exceeded the emission standard in 40 C.F.R. 61.252(a). On July 18, 2013, Energy Fuels submitted a second measurement schedule to Utah DAQ notifying the agency that it was going to perform two additional monitoring events in September and December of 2013. The CAA regulations do not permit Energy Fuels to submit a second measurement frequency schedule.

54. By submitting a second measurement frequency schedule, Energy Fuels violated the CAA's notification requirements for uranium mills at 40 C.F.R. § 61.253. This violation of the CAA -- 42 U.S.C. § 7412(f)(4) and § 7412(i)(3)(A) -- is enforceable under the CAA citizen suit provision.

FOURTH CLAIM FOR RELIEF
(Violation of the Clean Air Act and implementing regulations, Measurement Protocols 40 C.F.R. § 61.253

55. Each and every allegation set forth in this Complaint is incorporated herein by reference.

56. In June 2013, Energy Fuels took 100 radon-flux samples on the Cell 3 water saturated area, and 100 radon flux samples on the Cell 3 dry top surface area. Energy Fuels did not measure the side regions of Cell 3 in June 2013. Using the June measurements from the water saturated area and the dry top surface area, Energy Fuels calculated the radon flux for Cell 3 and determined that the radon flux was 22.7 pCi/m^2-sec.

57. In September 2013, Energy Fuels took 100 radon-flux samples on the Cell 3 dry top surface area. Energy Fuels failed to measure Cell 3's side regions in September 2013. Energy Fuels failed to sample Cell 3's water saturated area during the September measurement event. In calculating the mean radon flux for Cell 3 in September 2013, Energy Fuels used the measurements for Cell 3's water saturated area taken during the June measurement period and

the measurements for Cell 3's dry top surface area taken during the September measurement period. Using June and September data, Energy Fuels reported that the mean radon flux for the September 2013 sampling event was 28.4 pCi/m^2-sec. Energy Fuels thus violated Method 115's measurement requirements in September 2013.

58. In December 2013, Energy Fuels took 100 radon-flux samples on Cell 3's dry top surface area. Energy Fuels failed to measure Cell 3's side regions in December 2013. Energy Fuels failed to sample Cell 3's water saturated area in December 2013. In calculating the mean radon flux for Cell 3 in December 2013, Energy Fuels used the measurements for Cell 3's water saturated area taken during the June measurement period and the measurements for Cell 3's dry top surface area taken during the December measurement period. Energy Fuels thus violated Method 115's measurement requirements in December 2013.

59. The minimum ambient air temperature at Cell 3 during the December 2013 sampling period was 32 degrees Fahrenheit. Rain and snow fell on Cell 3 after the placement of the radon flux cannisters on December 3, 2013. Water puddles on the sampling site had a surface layer of ice approximately ½ inch thick, which melted by mid-day on December 4, 2013. Energy Fuels reported that the mean radon flux for the December 2013 sampling event was 10.00 pCi/m^2-sec. Method 115 mandates that the weather conditions and moisture content of the tailings be chosen to provide measurements indicative of the long-term radon flux of the pile. Energy Fuels thus violated Method 115's measurement requirements because the weather conditions and moisture content of the tailings during the December 2013 sampling event were not representative of the long-term radon flux from Cell 3.

60. Accordingly, Energy Fuels violated Method 115's measurement requirements at Cell 3 in 2013. This violation of the CAA -- 42 U.S.C. § 7412(f)(4) and § 7412(i)(3)(A) -- is

enforceable under the CAA citizen suit provision.

FIFTH CLAIM FOR RELIEF
(Violation of the Clean Air Act and implementing regulations, Radon-222 Emission Limit, 40 C.F.R. § 61.252(a)

61. Each and every allegation set forth in this Complaint is incorporated herein by reference.

62. The September and December 2013 emission measurements for White Mesa Mill's Cell 3 violated the regulatory notification requirements, and were not in accordance with Method 115 measurement requirements. As a result, the June 2013 measurement is the only valid measurement for Cell 3 in 2013. The June 2013 measurement of 22.7 pCi/m^2-sec exceeds the radon emissions standard set forth in 40 C.F.R. § 61.252(a). Energy Fuels violated 40 C.F.R. § 61.252(a)'s emission standard, its air permit, and the CAA's emission limit for Radon-222 at Cell 3 in 2013. See 40 C.F.R. §§ 61.252(a), 61.253. Energy Fuels' violations of the CAA -- 42 U.S.C. § 7412(f)(4) and § 7412(i)(3)(A) -- are enforceable under the CAA citizen suit provision.

PRAYER FOR RELIEF

WHEREFORE, Plaintiffs respectfully request that this Court enter judgment against Defendant and provide the following relief:

1. Declare that Energy Fuels has violated and is violating the Clean Air Act and issue such orders as are necessary to enforce the Clean Air Act emissions standards and limits, notification requirements, and measurement protocols;

2. Enjoin, through an injunction, Energy Fuels from conducting operations at White Mesa Mill until it complies with the Clean Air Act;

3. Enjoin, through an injunction, Energy Fuels from emitting Radon-222 in violation of the CAA standard;

4. Order, through an injunction, Energy Fuels to comply with the Clean Air Act's work practice standards applicable to uranium mills;

5. Order, through an injunction, Energy Fuels to comply with the Clean Air Act's radon flux measurement protocols and notification requirements applicable to uranium mills;

6. Order, through an injunction, Energy Fuels to take actions that remediate the adverse effects to public health and the environment from its Clean Air Act violations;

7. Order Energy Fuels to pay civil penalties for present and past violations of the Clean Air Act (42 U.S.C. § 7604; 40 C.F.R. § 19.4); and fund beneficial mitigation projects or supplemental environmental projects for present and past violations of the Clean Air Act (42 U.S.C. § 7604(g));

8. Award Plaintiffs' costs, including reasonable attorneys' fees and expert witness fees (42 U.S.C. § 7604(d)); and

9. Provide such other relief as the court deems just and proper.

Respectfully submitted this 1st day of October, 2014

/s/ Travis Stills

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ORAU

April 25, 2014

Thomas McLaughlin, PhD
U.S. Nuclear Regulatory Commission
11545 Rockville Pike
Mail Stop: T-8F5
Rockville, MD 20852

SUBJECT: PILOT STUDY REPORT FOR RADON EXHALATION MEASUREMENTS, OAK RIDGE, TENNESSEE DCN: 2052-TR-01-0(RFTA 11-016)

Dear Dr. McLaughlin:

Oak Ridge Associated Universities (ORAU), operating under the Oak Ridge Institute for Science and Education (ORISE) contract, is pleased to provide the enclosed final report that details the results of the Radon Exhalation Measurements Pilot Study. Comments on the draft version have been incorporated.

Please feel free to contact me, via my information below, or Tim Vitkus, at 865.576.5073, if you have any questions or comments.

Sincerely,

Nickolas Altic
Health Physicist
Survey Projects

NAA:fs

Enclosure

cc: T. Carter/FSME/DWMEP/DD/SP
S. Roberts, ORAU
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File/2052

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PILOT STUDY REPORT FOR RADON EXHALATION MEASUREMENTS

Nickolas Altic

Prepared for the U.S. Nuclear Regulatory Commission

ORAU
OAK RIDGE ASSOCIATED UNIVERSITIES

ORAU provides innovative scientific and technical solutions to advance research and education, protect public health and the environment and strengthen national security. Through specialized teams of experts, unique laboratory capabilities and access to a consortium of more than 100 major Ph.D.-granting institutions, ORAU works with federal, state, local and commercial customers to advance national priorities and serve the public interest. A 501(c)(3) nonprofit corporation and federal contractor, ORAU manages the Oak Ridge Institute for Science and Education (ORISE) for the U.S. Department of Energy (DOE). Learn more about ORAU at www.orau.org.

PILOT STUDY REPORT FOR RADON EXHALATION MEASUREMENTS OAK RIDGE, TN

Prepared by

N.A. Altic

Independent Environmental Assessment and Verification Program
Oak Ridge Associated Universities
Oak Ridge Institute for Science and Education
Oak Ridge, Tennessee 37831-0017

Prepared for the
U.S. Nuclear Regulatory Commission

FINAL REPORT

APRIL 2014

Prepared by Oak Ridge Associated Universities under the Oak Ridge Institute for Science and Education contract, number DE-AC05-06OR23100, with the U.S. Department of Energy under interagency agreement (NRC FIN No. F-1244) between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy.

ORAU

PILOT STUDY REPORT FOR RADON EXHALATION MEASUREMENTS OAK RIDGE, TN

Prepared by: _____ Date: 4/24/2014
N.A. Altic, Health Physicist
Independent Environmental Assessment
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Reviewed by: _____ Date: 4/25/14
W.P. Ivey, Laboratory Group Manager
Independent Environmental Assessment
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F.A. Templon, Quality Assurance Director
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Reviewed and approved for release by: _____ Date: 4/24/2014
T.J. Vitkus, Associate Director
Independent Environmental Assessment
and Verification Program

FINAL REPORT

APRIL 2014

CONTENTS

TABLES

FIGURES

ACRONYMS

AA	alternative action
CFR	Code of Federal Regulations
CV	coefficient of variation
DER	duplicate error ratio
DQO	data quality objectives
GPS	global positioning system
LAACC	large area activated charcoal canister
MDF	minimum detectable flux
PSQ	principal study question
RSS	ranked set sampling
VSP	Visual Sample Plan

PILOT STUDY REPORT FOR RADON EXHALATION MEASUREMENTS OAK RIDGE, TN

1. INTRODUCTION

Radon is a naturally occurring inert radioactive gas generated by the decay of radium. The three naturally occurring isotopes of radon are radon-219, radon-220, and radon-222—with radon-222 having the longest half-life of 3.8 days. Radium-containing material can introduce radon to the surrounding atmosphere by two interrelated processes: emanation and exhalation. The process of emanation occurs when a recoil radon atom reaches the interstitial space of the material, where it is considered to be in the unbound state. The emanation coefficient is defined as the ratio of the unbound to bound radon atoms. The emanation coefficient is material-dependent and also depends on the physical properties of the material. Once radon is in the interstitial material space, it is free to migrate towards the surface and is governed by two transport mechanisms: diffusion and active transport (Straden 1984). Exhalation refers to the unbound radon crossing the surface of the material into the atmosphere. Radon flux density (commonly referred to simply as radon flux) is the activity of radon exhaled over a surface area per unit of time, and commonly has units of $pCi/m^2 s$ or $Bq/m^2 s$.

Conventional uranium mill ore extraction processes yield large amounts of leftover material, or uranium mill tailings. After uranium extraction is complete, the mill tailings are placed in large piles for storage. These piles contain considerable concentrations of radium-226, thereby serving as sources for radon-222. The radon concentration present in mill tailings can be up to 1,000 times higher than the concentration in natural soils (Ferry et al. 2002). Because radon has been classified as a Group 1 human carcinogen by the International Agency on Cancer Research, regulatory agencies have enacted limits on the radon releases from mill tailing sites (IACR 1988).

In order to reduce radon emission, the uranium mill tailing impoundments are covered with earthen material. Current radon exhalation measurement methodologies are designed to simply satisfy regulatory requirements and are not useful for evaluating radon exhalation over time to detect trends. As discussed in Section 1.3, there are a number of environmental factors that impact radon exhalation that introduce varying degrees of fluctuation in the exhalation rate at a fixed location. This variability resulting from environmental factors may mask increasing trends in the exhalation

rate. If environmental factors could be accounted for, then unbiased measurements could be performed periodically in order to assess radon exhalation over time and detect any trends of regulatory concern.

1.1 REGULATORY REQUIREMENTS

The United States Code of Federal Regulations (CFR), Title 40, Part 61 and Appendix A, Criterion 6(1) sets the standards for emission of hazardous air pollutants. Subparts T and W set the standards for radon flux emission from mill tailing disposal sites and operating mill tailings sites, respectively. Radon flux emissions are limited to an average of 20 $pCi/m^2 s$ for both subparts. Method 115 in Appendix B Part 61 describes monitoring methods to demonstrate compliance with Subparts T and W. Radon flux measurements to quantify radon emission must be made annually per the regulations. In order to determine an accurate measurement of radon flux, Method 115 recommends that a measurement set, consisting of 100 sample locations, be made for each region of the tailing pile. The method states that water-covered areas do not require monitoring because the radon flux is assumed to be zero due to the water barrier.

1.2 MEASUREMENT THEORY

Radon flux from soils is commonly measured by the accumulator technique. This technique is performed by placing an inverted cup on the surface of interest of known surface area and collecting radon for a specified period of time. Radon flux can then be calculated based on the concentration rate of change with respect to time. Accumulators have two basic design types: closed and flow-through (Zarhorowski and Whittlestone 1996). The closed accumulator design does not exchange air between the sample chamber and the external environment. For the flow-through design, there is constant air exchange between the sample chamber and the ambient environment. The constant air exchange creates an equilibrium of radon concentration in the detector, from which radon flux can be calculated. There are several types of commercially available detectors to measure the change of radon concentration inside the accumulator.

The presence of an accumulator on the ground does not measurement surface can perturb the radon exhalation rate. Radon atoms may diffuse from the cup to the ambient atmosphere where the accumulator cup meets the soil. This phenomenon, referred to as back-diffusion, can reduce the concentration in the cup, thereby causing an underestimation of the radon flux. Two-dimensional

diffusion models have been developed to account for this back-diffusion (Mayya 2004, Aldenkamp et al. 1992). Moreover, Aldenkamp et al. proposes that the only way to estimate unperturbed radon flux is to measure radon concentration *in situ* (1992). For a fixed accumulator size, back-diffusion is directly proportional to radon flux. There are sampling methods that have been used for eliminating back-diffusion. These methods include the use of flow-through accumulator designs and/or short accumulation times (Mayya 2004 and Ferry et al. 2000). However, while these methods reduce back-diffusion, they may also limit radon concentration build-up in the accumulator, which may result in an increased minimum detectable concentration. Therefore, an *a priori* knowledge of radon flux must be known in order to determine if a correction for back-diffusion is required. When measuring areas with an expected high level of radon flux, back-diffusion effects should be mitigated. Because the radon exhaltion at uranium mill tailing sites are higher than those expected from natural soil, the methods for reducing back-diffusion previously discussed may be applicable.

1.3 FACTORS AFFECTING RADON EXHALATION

There are numerous interrelated factors that affect radon exhalation from the soil surface including soil type, atmospheric pressure, soil moisture (i.e., rainfall), soil temperature, and wind. It is difficult to quantify the change in radon exhalation based on these factors because of their interrelation (i.e., a precipitation event is generally associated with a drop in pressure). Therefore, the study also evaluated these factors, both independently and in combination, in order to gauge the significance of the impact of each factor to the radon flux.

Soil type plays an especially important role in radon exhalation. Radon exhalation is dependent on a number of individual soil parameters including porosity, radon diffusion coefficient, radium-226 concentration, and soil moisture. Sandy soils will trend towards higher radon exhalation rates than soils consisting of primarily clay. Uranium mill tailing sites are located primarily in the western portion of the United States where the soils tend to be more porous and have a lower moisture content, which will generally result in an increase in radon exhalation.

Schery et al. reported a negative correlation between atmospheric pressure and surface radon flux, but could not prove causality for the correlation (1984). Schery et al. found it difficult to show causality of pressure effects on radon exhalation for a diurnal time scale because several other

meteorological variables were changing on the same time scale. Their paper reported that pressure changes over a long time scale did occur when no other meteorological variables changed on the same time scale, during which radon exhalation was found to decrease with increasing pressure. In a similar study, Ferry et al. performed radon exhalation measurements on a simulated tailings pile. The pile consisted of a 0.8 m thick layer of mill tailings covered by a 1-meter thick layer of compacted soil. Exhalation measurements were initially collected on the uncovered pile. A much larger variation in atmospheric pressure was observed in that study than what was observed during this work—pressure ranged from approximately 960 hPa to 990 hPa for the Ferry et al. study. Radon exhalation rates ranged from approximately 0 to 12 $Bq/m^2 s$ (0 to 324 $pCi/m^2 s$). The tailings pile was exposed to the environment and the large variation in exhalation rate occurred after a rain event. At the beginning of the measurement period, there was little rainfall recorded and the radon exhalation was fairly constant, indicating that the impact atmospheric pressure has on radon exhalation is small.

Soil moisture, largely a function of precipitation, impacts the diurnal radon flux from the air-soil interface. Periods of precipitation result in decreased radon exhalation rates (Ferry et al. 2000, Schery et al. 1984). Schery et al. postulated that precipitation functioned to seal pores in the top 10 cm of soil, thereby forming a cap that lowers surface radon emission (1984). Method 115 (discussed previously) restricts radon flux measurements on tailings piles after a rain event. Interestingly, Straden et al. found that an increase in moisture content in concrete, shale, and soil led to an increase in radon emanation of up to a factor of 20, depending on the material (1984). The increase in radon exhalation was less pronounced for concrete than for the other materials tested. Moisture increases the amount of radon available for transport to the atmosphere but decreases diffusion through the source material. For a mill tailing site, the source is covered by soil; therefore, a rain event will affect primarily the cover layer by decreasing diffusion and not influence emanation in the ore.

There are conflicting reports about the degree to which temperature affects radon exhalation (Schery et al. 1984, Stranden et al. 1984). Schery et al. concluded that at best there was a weak positive correlation while Straden et al. found a significant increase in radon exhalation as temperature rose (1984). The variations in results may be explained by their measurement methodologies. Schery et al. measured radon flux on the soil while Straden et al. measured exhalation from individual samples in a laboratory setting. Intuitively, one might posit that radon

flux would increase with increasing temperature because the rate of diffusion is directly proportional to temperature.

Wind is another meteorological factor that has been weakly correlated to radon exhalation. Schery et al. was able to detect a slight enhancement of surface radon flux with wind speeds up to 7 m s^{-1} (1984). However, these effects were just within the limits of detection and are much less significant than other atmospheric effects.

2. OBJECTIVES

At the U.S. Nuclear Regulatory Commission's (NRC's) request, Oak Ridge Associated Universities (ORAU), working under the Oak Ridge Institute for Science and Education (ORISE) contract, developed and implemented the methodology to assess and quantify the impacts of atmospheric pressure and soil moisture on radon flux within a pilot-scale system. The study involved the development of a radon flux monitoring process capable of determining flux changes on a diurnal scale. The ability to measure radon flux on a diurnal scale is needed because atmospheric pressure can vary throughout the measurement period required of other exhalation monitors. This study also evaluated how the in-house developed continuous radon flux monitor compared to two other well-known radon flux monitors (i.e., the E-PERM and activated charcoal canister).

The intended use of this system is to assess the change in radon flux over time at a uranium mill tailing site. The primary purpose for the pilot study at ORAU's Oak Ridge campus was to develop a continuous radon flux monitor and work out any issues with the measurement system prior to field deployment. The pilot study was divided into two phases. Phase I involved the development of the continuous radon flux monitoring system. Phase II entailed testing the system under varying environmental conditions (e.g., atmospheric pressure and soil moisture).

3. DATA QUALITY OBJECTIVES

The data quality objectives (DQO) process provides a formalized method for establishing performance and acceptance criteria for plans designed to collect environmental data. DQO definition, implementation, and assessment are iterative processes, because review of comprehensive

data sets (i.e., historical data plus newly collected data) may result in the formation of new decisions, requiring the seven DQO steps to be repeated. The seven steps of the DQO process are as follows.

1. State the problem.
2. Identify the decision.
3. Identify inputs to the decision.
4. Define the study boundaries.
5. Develop a decision rule.
6. Specify limits on decision errors.
7. Optimize the design for obtaining data.

3.1 STATE THE PROBLEM

The first step of the DQO process was to state the problem in a broad sense so that the focus of the project was unambiguous. Environmental variables such as atmospheric pressure, soil moisture, etc., can affect the variability in radon flux from soil, especially in combinations on the diurnal scale. There is a need to measure the impact these variables have on radon exhalation, in order to assess the unbiased radon exhalation rate at a uranium mill tailing impoundment over time.

3.2 IDENTIFY THE DECISION

The second step in the DQO process identified the principal study question (PSQ) and alternate actions (AAs) or outcomes that may result based on the answers to the PSQ. A decision statement is then made by combining the PSQ and AAs into a decision statement. Table 3.1 presents the PSQ and AAs and the resulting decision statement.

Table 3.1. Pilot Study Design Process	
Principal Study Question	**Alternative Actions**
Can ORAU develop a measurement system/process to assess radon exhalation that takes into account environmental factors within a pilot-scale system? Additionally, will this device be suitable for field use at a uranium mill tailing impoundment to evaluate radon exhalation over time?	1. This type of system can be developed and is suitable for field use. 2. This type of system can be developed, but is not suitable for a long term measurement period. 3. This type of system cannot be developed. Current measurement methodologies must be relied on to assess radon exhalation over time.
Decision Statement	
Determine that a radon flux measurement system/process is or is not capable of assessing the impact on the flux from the various environmental factors.	

3.3 IDENTIFY INPUTS TO THE DECISION

The third step in the DQO process determined what information was needed to resolve the decision statement produced in Step 2. For this project, the source of information needed to resolve the decision statement came from two primary sources: peer-reviewed literature and testing of a radon flux measurement system.

The first information source was from published literature, which included peer-reviewed journals as well as a previous ORAU/ORISE document (ORAU/ORISE 2011). These literature and report sources were used to aid in the design of the system. The data collected by the system were also compared with the data reported in the literature.

The second source of information was the data generated during testing of the system. The data generated described how three different flux monitors (discussed in Section 5.3) respond under the same conditions, relative to each other. The system also tested under varying environmental conditions, which would provide proof-of-concept that the system would be suitable for field use,

thus demonstrating that the impacts of environmental conditions on radon flux can be assessed and subsequently account for measurement location-specific variability.

3.4 DEFINE THE STUDY BOUNDARIES

In the fourth step of the DQO process, the target population of interest, spatial, and temporal boundaries were established. The target population for the testing phase of this project was the study of the radon flux variability that results from changing environmental conditions. In terms of physical space, this study was limited to the ORAU-managed South Campus in Oak Ridge, Tennessee.

3.5 DEVELOP A DECISION RULE

The purpose of step 5 in the DQO process was to integrate the previous DQO steps into a single statement that describes a logical basis for choosing among alternative actions. If a system as described in the PSQ cannot be established, then ORAU will determine the next best solution to the problem statement.

3.6 SPECIFY LIMITS ON DECISION ERRORS

The largest possible source of error in this study was from inconsistent response from the continuous radon monitor. In order to limit this error, side-by-side measurements were made with an E-PERM and large area activated charcoal canisters (LAACCs). Average radon flux values as measured by the continuous flux monitor were compared with values obtained with the E-PERM and the LAACC (the E-PERM provides an average flux during the measurement interval).

3.7 OPTIMIZE THE DESIGN FOR OBTAINING DATA

Details of the pilot study are outlined in Section 4.

4. MATERIALS AND METHODS

4.1 MATERIALS

Materials used for this study are outlined below

4.1.1 Radon Flux Monitors

Details of each radon flux monitor are described below.

4.1.1.1 Continuous (Model 1029)

The radon flux monitor developed consisted of two main parts: an accumulator and a continuous radon monitor. The accumulator was made of a fairly thick plastic container intended to prevent diffusive losses of radon through the accumulator wall. Mounting straps were fastened to the top of the accumulator to hold the radon monitor in place. An aluminum collar was fastened to the edge of the accumulator to allow the monitor to be pressed into the soil. All seams were filled with a compound to prevent radon loss.

The second portion of the flux monitor consisted of the continuous radon monitor, which was a Sun Nuclear Model 1029. The Model 1029 has the capability to record and digitally store radon concentration measurements at intervals specified by the user. This particular model also has the ability to record atmospheric pressure, relative humidity, and temperature. Per the manufacture, the measurement range for radon is 0.1 to 9,999 pCi l^{-1}, with an accuracy of 25% (Sun Nuclear 2010). The method of determining radon flux using this monitor is presented in Appendix A. A picture of the Model 1029 radon exhalation monitor placed on the small exhalation bed is shown in Figure 4.2.

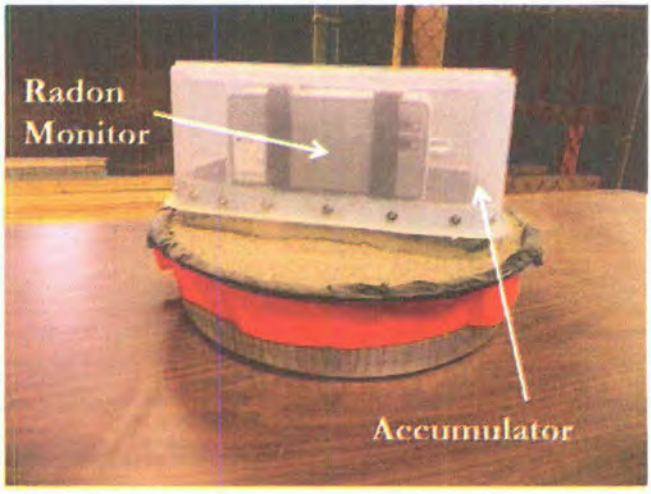

Figure 4.2. Model 1029 Radon Exhalation Monitor

The minimum detectable flux (MDF) was determined to be 0.06 pCi/m^2 s, based on the manufacturer's specifications and a half-hour measurement interval. The MDF was calculated by:

$$MDF = \left(\frac{dC}{dt}\right)_{min}\left(\frac{V}{S}\right) = \left(\frac{27.4Bq/m^3}{0.5h}\right)\left(\frac{0.01m^3}{0.07m^2}\right)\left(\frac{27.027\,pCi\,h}{3600\,s\,Bq}\right) = 0.06\frac{pCi}{m^2 s}$$

Where:

$(dC/dt)_{min}$ = minimum detectable rate of concentration increase

V = net volume in the accumulator

S = surface area of the accumulator

4.1.1.2 Activated Charcoal

A LAACC was fabricated in order to compare the Model 1029 radon flux monitor to a widely accepted standard. The LAACC was fabricated based on the design presented in *Radon Flux Measurements on Gardinier and Royster Phosphogypsum Piles near Tampa and Mulberry, Florida* (EPA 1986). Radon is adsorbed onto the charcoal, and then analyzed by gamma spectroscopy. The gamma spectroscopy results, charcoal weight, measurement time, and canister surface area were used to calculate the radon exhalation rate. The MDF of the activated charcoal canisters was 0.01 pCi/m^2 s based on a measurement time of 24 hours. The MDF was calculated by:

$$MDF = \frac{(MDC)(w)}{(t)(S)} = \frac{\left(0.23\frac{pCi}{g}\right)(180g)}{(24h)(0.05m^2)}\left(\frac{1\,h}{3600\,s}\right) = 0.01\frac{pCi}{m^2\,s}$$

where,

MDC = minimum detectable concentration of gamma spectroscopy system

w = mass of charcoal used per measurement

S = surface area of LAACC

t = measurement time

4.1.1.3 E-PERM

This type of flux monitor uses a modified E-PERM H electret ion chamber that features a 180 cm^2 diffusion window. The rate of discharge of the negatively charged electret is related to the radon flux from soil. The manufacture reports a MDF of 0.24 and 0.08 $Bq/m^2 s^1$ (6.5 and 2 $pCi/m^2 s^1$) for a measurement time of 8 and 24 hours, respectively, using long-term electrets (Stieff et al. 1996).

4.1.2 Radon Exhalation Bed

In order to provide a consistent radon flux, an exhalation bed was constructed. A layer of finely ground uranium ore was spread over the bottom of a Hardigg case with dimensions of 84 cm wide by 53 cm in length. Approximately 12 kg of uranium ore was used. A 10-centimeter thick simulated cover layer of fill dirt was then spread on top of the uranium ore. The layer of fill dirt allowed for the radon generated from the ore to diffuse to the surface and create a uniform flux at the soil/radon flux monitor interface. A sheet of porous landscaping fabric was placed between the ore and fill dirt allowing for easy recovery of the ore. The landscaping fabric was chosen so that radon could freely diffuse from the layer of uranium ore to the layer of fill dirt. Figure 4.1 presents a schematic of the radon exhalation bed.

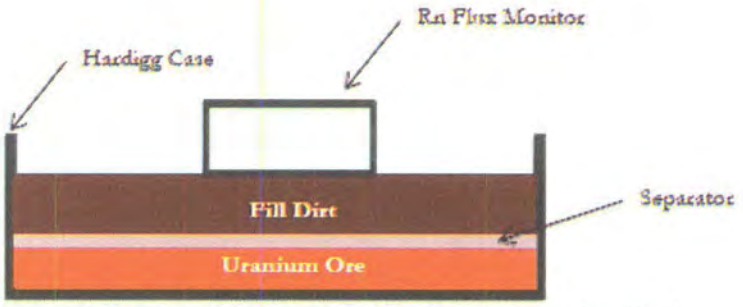

Figure 4.1. Schematic of Radon Exhalation Bed

A smaller radon exhalation bed was also constructed. The smaller bed allowed for a higher concentration of uranium per unit area while keeping sufficient fill dirt for uniform exhalation. The higher quantity of ore per area allowed for a much higher radon exhalation rate to be achieved than with the larger bed. The schematic for the smaller bed was the same as shown in Figure 4.1 only that the Hardigg case was replaced with a circular metal pan with a diameter of 39 cm and a depth of 9.5 cm. The smaller bed also allowed for the quantity of uranium ore to be easily varied.

4.1.3 Atmospheric Chamber

In order to vary atmospheric pressure by factors more than can be observed naturally, an atmospheric chamber, shown in Figure 4.3, was constructed to artificially vary the ambient pressure around the exhalation bed. The atmospheric chamber consisted of a 55-gallon steel drum fitted to a vacuum pump and a pressure gauge. A seal was placed around the drum lid in order maintain

pressure inside the drum. Fans were mounted inside the chamber in order to ensure proper air mixing in the chamber.

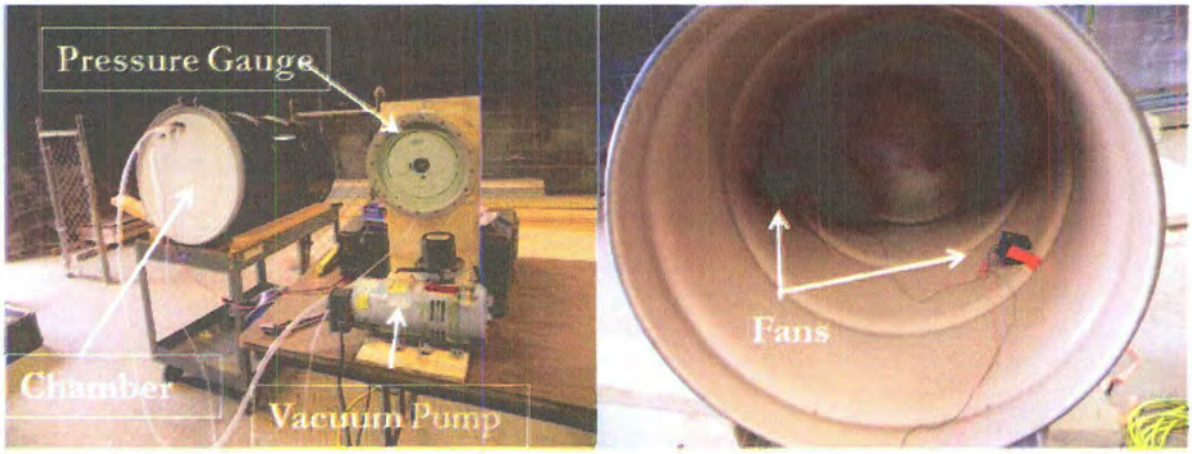

Figure 4.3. Picture of the Atmospheric Chamber

4.2 METHODS

4.2.1 Investigation of Atmospheric Pressure Effects

Influence of atmospheric pressure on radon flux was evaluated in two ways. First, measurements were collected with the Model 1029 radon flux monitor placed on the larger exhalation bed. Measurements were collected daily from July 26, 2012 to September 19, 2012. The monitor was placed on the bed and was allowed to accumulate radon for at least one hour. The first three data points—corresponding to one hour of accumulation time—were used to calculate the rate of change in radon concentration inside the accumulator with respect to time (dC/dt), as discussed in Appendix A.

For measurements performed with the atmospheric chamber, the large exhalation bed and the Model 1029 were placed inside the chamber, and the lid was sealed. The vacuum pump was turned on until the desired pressure was reached. The radon concentration was measured over time and the exhalation rate was calculated using the same method as described in Appendix A—the same as for calculating radon flux with the accumulator. For measurements made with the atmospheric chamber, the 55-gallon steel drum served as the radon accumulator.

4.2.2 Investigation of Soil Moisture Effects

The fill dirt layer (Figure 4.1) was first dried overnight in an oven at 100 °C. Deionized water was added to the fill dirt of the smaller exhalation bed to assess the affect of soil moisture on radon flux and to determine if the Model 1029 would be able to differentate between varying levels of water content. Enough water was added so that the fill dirt contained 0%, 5%, 10%, and 15% water by weight. The wet dirt was placed on top of the uranium ore and the radon exhalation was measured with the atmospheric chamber. Soil with a water content of 0% by weight will abosrb moisture from the ambient air. However, with the short measurement time, it was assumed that the soil moisture remained at 0% during the measurement.

4.2.3 Inter-comparison of Flux Monitors

Radon flux measurements were collected using four different monitors to assess inter-comparability. The four monitors used in the inter-comparison were the three monitors discussed in Section 4.2 and the atmospheric chamber discussed in Section 4.3. The small exhalation bed was used for all inter-comparison measurements. The uranium ore contents were varied from 0.2 kg to 10.7 kg. Measurements with all four monitors were collected at each quantity of uranium ore. Radon was allowed to equilibrate in the cover layer before any measurements were made. Additionally, measurements with the LAACC, E-PERM, and Model 1029 were made on soil to assess background inter-comparability.

Repeated measurements were made with the LAACC to assess measurement variability. A total of four 24-hour measurements were made on the small exhalation bed. The charcoal was then analyzed by gamma spectroscopy and the radon-222 activity collected per hour was calculated.

5. RESULTS AND DISCUSSION

The results of the atmospheric pressure, soil moisture, and inter-comparison measurements are summarized below.

5.1 ATMOSPHERIC PRESSURE

Radon exhalation measurements collected under naturally varied atmospheric conditions are presented in Figure 5.1. Atmospheric pressure during the measurement periods ranged from 989 to

1,001 hPa and the associated radon exhalation values varied from 2.18 to 11.7 pCi/m^2 s^1. The average width of the 95% confidence interval for all measurements was 18% of the observed mean range in radon exhalation. The radon exhalation measurement data in Figure 5.1 have a slight negative correlation with respect to atmospheric pressure.

For the ORAU study, a linear regression was applied to the data, represented by the red line in Figure 5.1. The resulting R^2 value was negative at -0.04, indicating that the data do not fit the linear regression model. A negative R^2 value is generated by the graphing software when the variance of the regression is worse than the variance resulting from fitting a horizontal line. As shown in Figure 5.1, two data points are significantly higher than the rest. However, nothing suggests that that the two data points are questionable and, therefore, cannot be excluded from the regression model. Other environmental factors for those two data points recorded by the Model 1029, temperature and relative humidity, were compared to the rest of the population. As seen in Table B-1, temperature was not appreciably different for those two data points compared to the rest of the population. Relative humidity for those two points was slightly higher than the other measurements but is likely not the cause. An increase in relative humidity would decrease the sensitivity of the radon monitor causing an underestimation of the radon concentration.

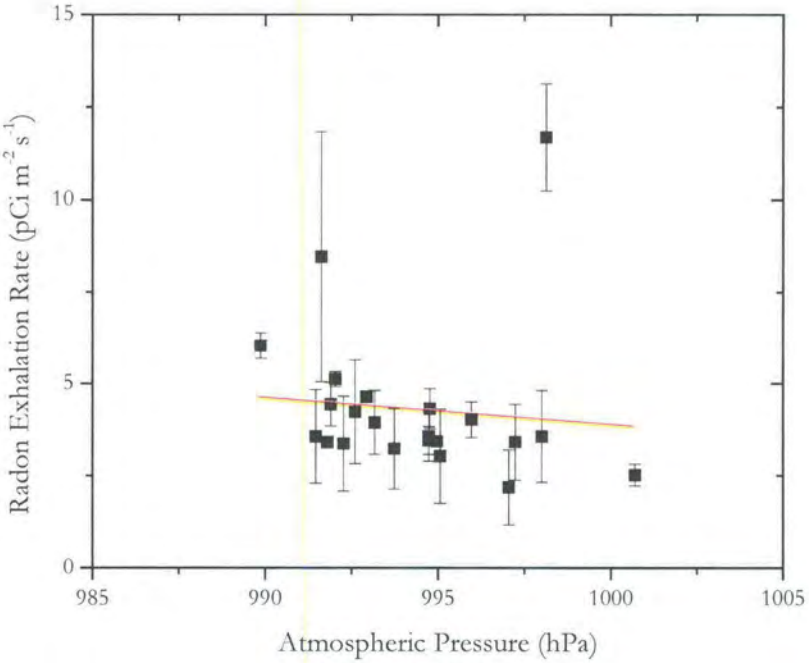

Figure 5.1. Radon Exhalation vs. Normal Atmospheric Pressure

Figure 5.2 represents radon exhalation measurements made while the pressure was varied with the atmospheric chamber. Ambient pressure inside the chamber ranged from 751 to 1,170 hPa and the resulting radon exhalation ranged from 4.51 to 7.90 pCi/m^2 s. The pressure range represents a much wider range than what would be observed under normal conditions. Comparing Figures 5.1 and 5.2, the pressure range in Figure 5.1 is only 3% of the range in Figure 5.2. The pressure was varied far outside of the normal range in order to achieve a better fit of the data.

A linear regression was applied to the data and the resulting R^2 value was 0.17, which represents a better fit than the previous data set. The resulting R^2 value means that only 17% of the variation in radon exhalation can be explained by the variation in the ambient pressure. The small R^2 value indicates that the regression performed on the data in Figure 5.2 is not useful for application in the field. A possible cause for the inadequacy of the model is that the Model 1029 may not be sensitive enough to resolve the change in radon exhalation due to atmospheric pressure alone. The average width of the 95% confidence interval of all measurements is 53% of the observed range in radon exhalation. A trend may be more pronounced, resulting in a higher R^2 value, if the measurement error is significantly decreased.

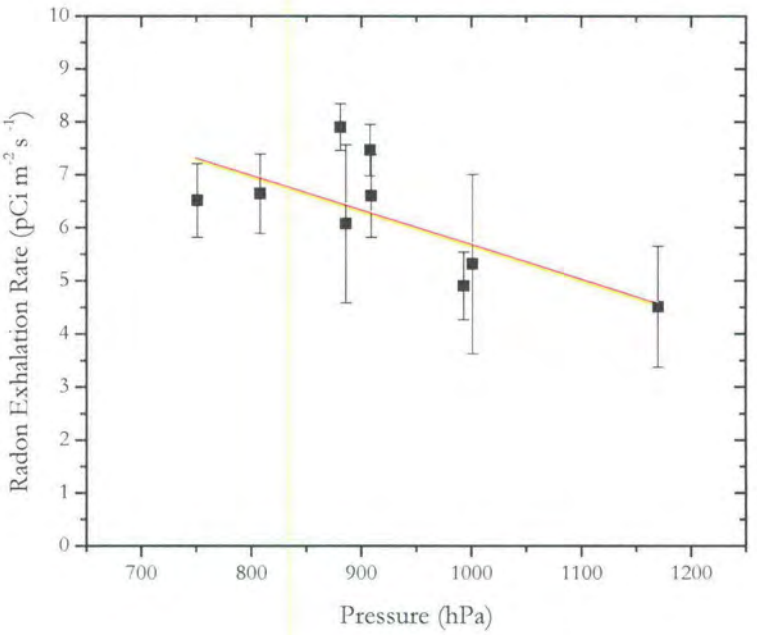

Figure 5.2. Radon Exhalation vs. Ambient Pressure Outside of Normal Range

5.2 SOIL MOISTURE

Radon exhalation was found to remain relatively constant with water content in the fill soil between 0% and 5% (% by weight). When the water content was between 5% and 10%, radon exhalation began increasing with increasing soil moisture. Figure 5.3 shows the relationship between radon exhalation and the fill soil percent moisture. The barrier between the uranium ore and fill dirt was permeable to water. As the moisture content in the fill layer increased, more water was available to penetrate into the ore layer. The moistened layer of ore would have a much greater emanation factor according to one study (Straden 1984). Under dry soil conditions, the range of the recoil radon-222 atoms is greater than the distance between soil particles. As water content in the soil increases, the air in the soil pores is replaced by water, which stops the recoil atom inside the soil pore. The radon is then free to diffuse through the soil. The soil moisture was not expected to infiltrate the ore layer; this effect is the cause of the exhalation rate increasing with water content.

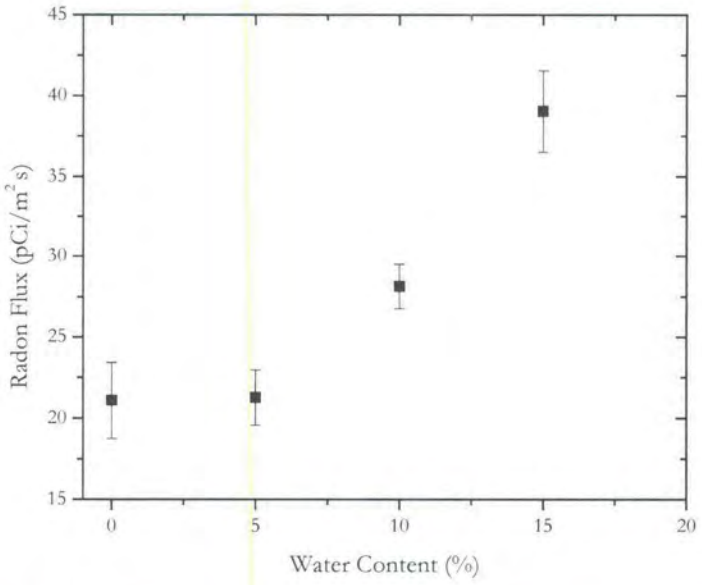

Figure 5.3 Radon Exhalation Rate as a Function of Water Content in the Fill Dirt

5.3 MEASUREMENT SYSTEM INTER-COMPARISON

Radon exhalation rate vs uranium ore quantity for each of the measurement systems is presented in Figure 5.4. At a relatively high uranium ore weight, the LAACC and the atmospheric chamber are in good agreement. However, the Model 1029 and E-PERM under-responded relative to the atmospheric chamber and LAACC. As the quantity of uranium ore decreased, the responses of the Model 1029 and E-PERM began to converge to the responses of the atmospheric chamber and LAACC. For measurements made on background soil, the difference between the E-PERM and the LAACC were less substantial. The radon exhalation rate for the background soil was 0.15 ± 0.01 pCi/m^2 s as measured by the LAACC which is in agreement with the E-PERM's result of 0.14 pCi/m^2 s. The model 1029 malfunctioned during the background level inter-comparison and returned a result of approximately 0 pCi/m^2 s. Due to project deadlines the issue was not able to be resolved.

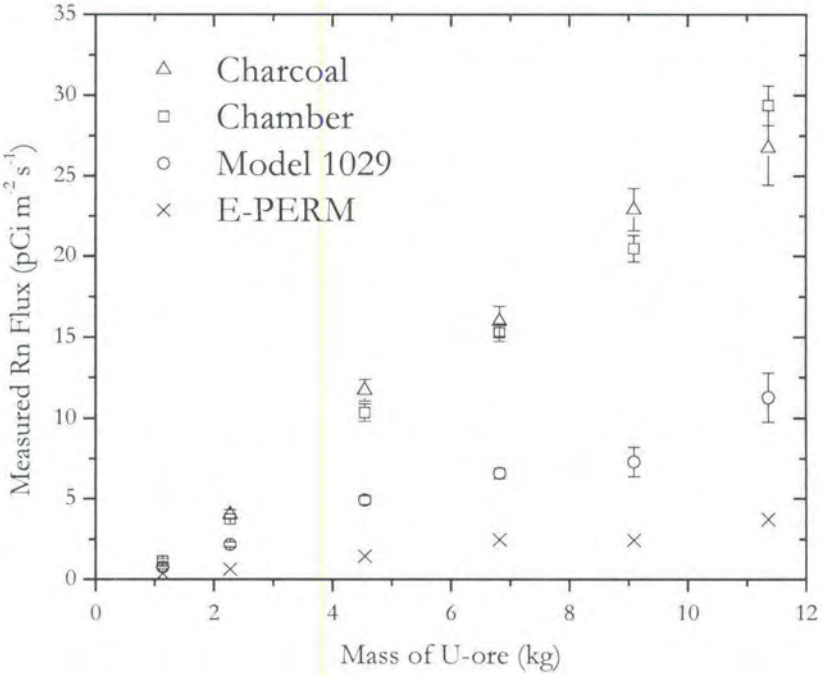

Figure 5.4. Results of the Inter-comparison Exercise

The results presented in Figure 5.4 prompted an investigation to determine the cause of the under–response of the Model 1029 and E-PERM relative to the LAACC and atmospheric chamber. For a fixed accumulation volume and measurement period, the magnitude of back-diffusion is proportional to radon exhalation. This means that at a higher radon exhalation, the effect of back-diffusion will be more pronounced. The data presented in Figure 5.4 indicate that the Model 1029 and E-PERM exhalation monitors suffer from significant back-diffusion effects, causing an under-response relative to the LAACC and atmospheric chamber. Accumulator volume can also impact the degree of back-diffusion. At a given radon exhalation rate, decreasing the accumulator volume will increase susceptibility to back-diffusion. The accumulator volume of the E-PERM is 1×10^{-4} m^3, which is significantly less than that of the Model 1029 at 1×10^{-2} m^3. This difference in volume explains why the back-diffusion effect on the E-PERM is more pronounced. The atmospheric chamber and LAACC do not suffer from back-diffusion due to their specific designs. The accumulator volume in the atmospheric chamber is very large relative to the soil gas volume in the exhalation bed and for the LAACC back-diffusion is not an issue due to the flow-through

design. The data also suggest that even a short accumulation time, as identified in the literature, does not significantly reduce the effect of back-diffusion.

Because the LAACC is the widely accepted standard for radon exhalation measurements, the results of the Model 1029 and the E-PERM were compared directly with the results of the LAACC. The difference in results was dependent on the quantity of uranium ore present in the bed (i.e., dependent on the magnitude of back-diffusion). It was found that the negative bias of the responses, relative to the LAACC, ranged from 12% to 68% for the Model 1029 and 58% to 89% for the E-PERM. Figure 5.4 shows how the back-diffusion is dependent on radon exhalation for the E-PERM and Model 1029. The data presented in Figure 5.4 are consistent with the theory of back-diffusion. That is, with increasing uranium ore mass, the concentration inside the accumulator will increase. With the increasing concentrations within small, non-flow through accumulator design, the effects of back diffusion on the exhalation measurement negative bias also increases.

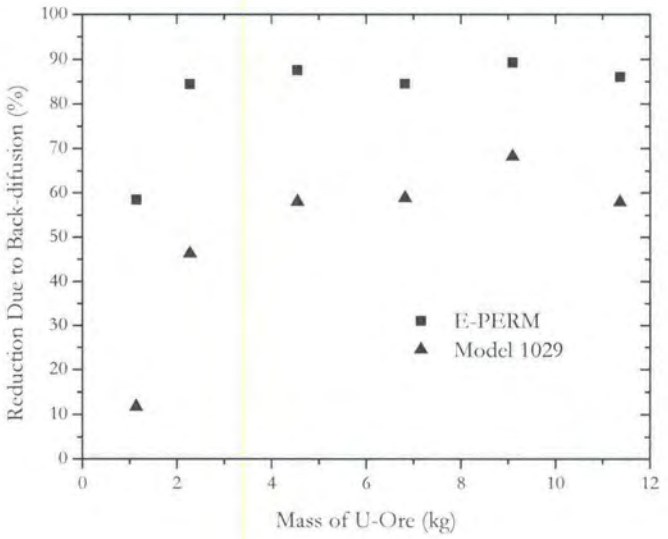

Figure 5.4. Reduction in Monitor Response Relative to the LAACC

Several articles have presented the results of inter-comparison tests with a number of radon exhalation monitors (Grossi et al. 2011; Hutter and Knutson 1998). Grossi et al. reported a fairly good agreement between the monitors with a coefficient of variation (CV) from 10% to 23% while Hutter Knutson reported a CV of 34%. However, the data presented in these articles were collected

from areas where the radon exhalation level was very small compared to the levels in the small exhalation bed used in this study. The maximum recorded radon exhalation value from the aforementioned articles was 1.2 pCi/m^2 s compared to a maximum value of 27 pCi/m^2 s from the exhalation bed.

Figure 5.5 shows the activity collected per hour by each individual measurement; the measurements have an average relative error. The variability measurements with the LAACC were not performed under identical atmospheric condition. However, based on the data presented in Section 5.1, the variability introduced by atmospheric pressure changes is small relative to the measurement uncertainty.

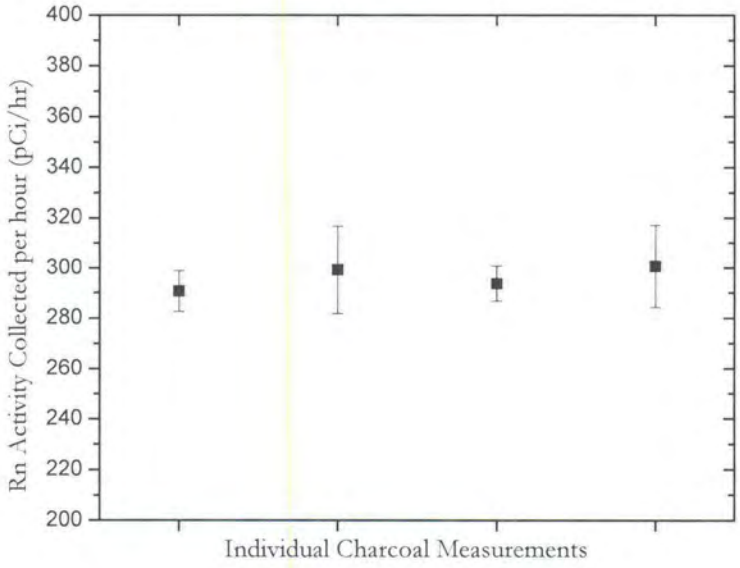

Figure 5.5. Repeated Measurements Using the LAACC

6. SUMMARY AND CONCLUSIONS

6.1 ATMOSPHERIC PRESSURE

Radon exhalation rate was found to have a slight negative correlation with atmospheric pressure (the exhalation rate decreased with increasing atmospheric pressure), which was expected based on the literature review. However, the linear regression model applied to the normal atmospheric data was

not valid, as indicated by the negative R^2 value. The data set for normal atmospheric pressure had two suspect data points present. These suspect data were not removed from the regression model as there was no evidence to question the data quality.

When atmospheric pressure was varied outside of the range of naturally occurring pressure differentials—the lowest and highest recorded pressures were 751 and 1,170 hPa, respectively—the relationship between radon exhalation and atmospheric pressure was stronger. The linear regression model applied to the second set of atmospheric data yielded an R^2 value of 0.17, which is better than the model applied to the normal atmospheric data set.

The measurement uncertainty of the Model 1029 was much larger than the variation in radon exhalation due to atmospheric pressure. The average width of the 95 % confidence interval of all measurements was 18% and 53% of the observed range in exhalation for the normal and artificially varied atmospheric pressure, respectively. This would make it difficult to quantify small changes in radon exhalation due to normal environmental variation in atmospheric pressure. If it were possible to reduce the measurement error, a better relationship may be established.

6.2 SOIL MOISTURE

Radon exhalation was found to increase significantly with increasing soil moisture.. The moisture in the soil layer infiltrated the ore layer which greatly increased the emanation power of the ore. The increase in emanation from the ore was enough to overcome the decrease in exhalation caused by moisture in the soil layer, thus resulting in a net increase in radon exhalation. Radon exhalation increased from 20 pCi/m^2s to 38 pCi/m^2s when percent moisture in the fill dirt layer increased from 0 to 15%. Thus, a valid relationship between soil moisture and radon exhalation could not be established with the current experimental setup. Further efforts were not pursued due to the results of the inter-comparison, discussed in Section 6.3, as a valid relationship between radon exhalation and soil moisture would not impact the overall outcome.

6.3 INTER-COMPARISON

Based on the results of the inter-comparison study, radon back-diffusion was causing the under response for both the Model 1029 and E-PERM. Previous inter-comparison exercises, as mentioned in the Section 5.3, were performed at radon exhalation levels close to background. However, the

concentrations of radon associated with uranium mill tailings are orders of magnitude higher than the concentrations encountered in background. Therefore, a major recommendation from the study is to ensure that the selected monitoring system has been evaluated for performance with the anticipated exhalation measurement conditions.

Therefore, the inter-comparison study resulted in the following conclusions for the measurement systems. The Model 1029 radon exhalation monitor would not be very useful for radon exhalation measurements at a uranium mill tailing site. This monitor is significantly affected by back-diffusion when performing measurements at an area with a high radon exhalation background. Therefore, because of back-diffusion issues, the Model 1029 is not considered a viable system for assessing radon exhalation across uranium mill tailing piles. The findings of the inter-comparison exercise result in the selection of option 3 from the list of AAs in Table 3.1. Therefore, a more accepted measurement method, such as activated charcoal, must be relied upon to assess radon exhalation over time.

7. PATH FORWARD

As a result of the data collected during the pilot study, the DQOs were reevaluated. As stated in Section 3.5, if the problem statement could not be adequately addressed, then ORAU would determine the next best solution. The following subsections provide a general overview of an alternate method to assess radon exhalation at a uranium mill tailings site over time. Specific procedures would be detailed in the project-specific-plan. The proposed method involves collecting periodic radon exhalation measurements at a mill tailings site and evaluating the trend in measurements over time, if any. Previous radon exhalation data would only be viable if the measurements were collected from the same locations periodically.

7.1 TREND TESTING

There are several statistical methods for evaluating trends over time (Helsel and Hirsch 2002; Meals et. al. 2011).Two trend tests are recommended. First, the Mann-Kendall test could be performed on the radon exhalation data set collected over time. The Mann-Kendall test is a nonparametric test and the values being tested do not require an underlying distribution assumption. The effects of

covariates such as atmospheric pressure, soil moisture, and temperature may mask any apparent trend. If a reasonable linear regression can be obtained between radon exhalation and any of the covariates, then the covariate influence on flux can be accounted for. Based on the results of the literature review and this study, soil moisture is expected to dominate the impact on flux over that of all other covariates. If the covariates could be successfully removed, then a second trend test can be performed on the residual (a residual is the difference between the actual measurement and the predicted value) from the regression model. Should flux residuals increase over time then it can be concluded that radon exhalation is increasing. If the covariates cannot be removed, then a simple trend test, such as the Mann-Kendall, could still be used on the data set. The sensitivity of the trend test is dependent on the rate of change of radon exhalation over time, if any, and thus cannot be predicted before mobilization to the site. A small, gradual increase over time will require more measurements (time) to detect than a large increase over a short period of time.

Exhalation measurements should be performed periodically; other covariates such as atmospheric pressure, soil moisture, and temperature should be recorded as well. The covariates should be averaged over the measurement period. The trend analysis should be performed at each measurement location. A test on the average exhalation rate is not performed as the average could hide small changes in individual locations. The null hypothesis (H_0), or assumed base condition, is that there is no trend in the radon exhalation rates. The alternative hypothesis (H_A) is that there is a trend present in the radon exhalation rates. The confidence level of the test should be set at 95%.

7.2 RADON EXHALATION DATA SET

There are two potential data sources for the trend test, one being previous radon exhalation measurements to satisfy regulatory requirements. The other potential data set would be generated by performing radon exhalation measurements for the sole purpose of trend testing.

7.2.1 Historical Data

A site that has numerous years of radon exhalation data could be selected for a retrospective trend analysis. A simple trend test could be performed on the mean exhalation rate. The mean rate would need to be used as it is unlikely that the measurement locations would be the same for each data set. Using previous data has the advantage that the data analysis cost is relatively small compared to

collecting new data. However, a major disadvantage is that specific locations could not be evaluated over time.

7.2.2 Collected Data

A large enough number of measurement locations must be selected so that the results can be representative of the tailings impoundment. The measurement results should be representative of the tailing site so they could be extrapolated to the entire site, and thus decisions made about the study boundary would be representative of the entire impoundment. Therefore, a ranked-set sampling (RSS) scheme is proposed to select the measurement locations. Ranking locations would be assigned a low, medium, or high value dependent upon a static NaI measurement. The number and placement of RSS measurement locations would be determined using Visual Sample Plan (VSP). A large number of measurements is expected based on the results of national emission standards for hazardous air pollutants monitoring at the Canon City facility in Colorado where radon exhalation values varied by up to a factor of 100 (Cotter 2009). Measurements locations would be recorded with global positioning system (GPS) equipment.

Two of the underlying assumptions of the proposed trend testing process are that 1) radon exhalation at measurement locations would be expected to correlate proportionately with the relative concentration of radon decay products at a given location, and 2) radon exhalation at measurement locations increase the closer the material is to the surface. In other words, tailing pile areas with high concentrations close to the surface and with a thinner cover layer would be expected to have both the highest exhalation rates and should also show an increasing gamma radiation signature. These assumptions must be true in order to rank measurement locations with a NaI detector. Therefore, gamma walkover scans would be used to select judgmental radon exhalation measurement locations, both high and low. The judgmental locations would then be selected for routine monitoring. Gamma walkover scans would be performed during each site visit to ensure that areas of the study boundary are not changing relative to other locations (i.e., locations with the highest gamma radiation levels should remain high and locations with a low gamma radiation detector response should remain low relative to each other). NaI detectors would be coupled to GPS equipment that enable real-time gamma count rate and spatial data capture. The gamma data collected from each campaign could also be evaluated over time to identify trends in the gamma

signature from the pile. These data would provide a secondary standard for evaluating cover performance, especially when posted together with the flux measurement data.

7.2.2.1 Radon Exhalation Monitor

Measurements are proposed to be collected using the LAACC method as specified in Method 115b, Appendix B to 40 CFR 61. Additionally, the LACCs will be shielded from direct sunlight to minimize heating of the charcoal. Duplicate measurements are recommended by co-locating LAACCs at 10% of the measurement locations. The duplicate measurements would be evaluated using the duplicate error ratio (DER). A DER less than 3 indicates a 99% confidence that the two measurements are in agreement. Measurement times will be kept shorter than 24 hours to minimize the effects of temperature and humidity on radon adsorption onto activated charcoal.

$$DER = \frac{|S-D|}{\sqrt{(Us^2)+(Ud^2)}} = \leq 3$$

Where :
S = Measurement result
D = Duplicate result
Us = Measurement uncertainty (one-sigma level)
Ud = Duplicate uncertainty (one-sigma level)

Charcoal samples would be analyzed using solid-state gamma spectroscopy. Analyzing samples by gamma spectroscopy would provide a lower relative error when compared with systems using a NaI detector.

7.4 LOCATION OF SITE AND FREQUENCY OF MEASUREMENT EVENTS

A mill tailings site for this study has yet to be selected. One possible site is the Gas Hills site located approximately 60 miles east of Riverton, Wyoming. This site is proposed because of the potential support from site personnel. ORAU provides support to the state of Pennsylvania. It is possible an arrangement could be made to perform the proposed study at the abandoned tailing pile in Canonsburg, Pennsylvania. One factor that would be considered when selecting the site would be whether or not the tailing impoundment was covered by rip-rap. The rip-rap would need to be removed at each measurement location, which may not be feasible.

The frequency of measurements is yet to be determined. The site geographic location may seasonally constrain measurement events.

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APPENDIX A
EXHALATION RATE CALCULATIONS

The following sections describe how radon exhalation rate was calculated using the Model 1029 monitor. The minimum detectable flux (MDF) is also presented.

A.1 CALCULATION OF RADON EXHALATION RATE

When measuring radon exhalation with the closed can technique, radon concentration inside of the accumulator will increase with respect to time. The radon concentration profile over time will follow an exponential ingrowth, as shown in Figure A.1. Eventually equilibrium will be reached inside of the accumulator where the radon concentration is not changing over time. The rate of change of radon concentration with respect to time (dC/dt) remains constant initially then slowly decreases as the steady state is reached. However, when performing closed can measurements environmentally there are other factors that affect the buildup of radon inside the accumulator.

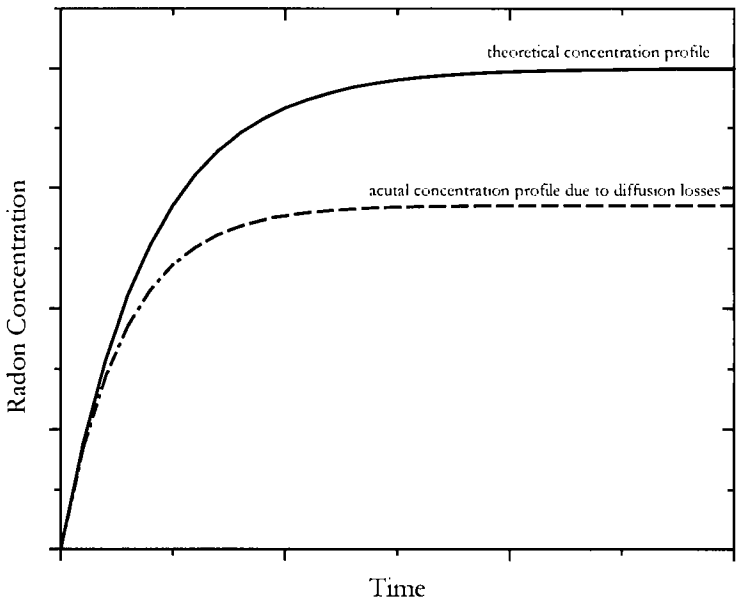

Figure A.1. Theoretical vs Actual Radon Concentration Profile for Closed Can Measurements

As the radon concentration inside of the accumulator increases the probability increases for radon atoms to diffuse back into the soil, where they are then free to diffuse outside of the accumulator.

This process of back-diffusion suppresses the steady state radon concentration inside of the accumulator, as shown by the dashed line in Figure A.1. The magnitude of the suppression is dependent on the accumulator volume and the radon exhalation rate, both of which determine how fast the radon concentration increases.

Radon concentration at a given time (t) can be calculated by,

$$C(t) = \frac{FA}{V\lambda_e}[1 - exp(-\lambda_e t)] \qquad \text{(Equation 1)}$$

where F is the undisturbed radon exhalation rate, λ_e is the effective time constant for radon buildup, A is the surface area of the accumulator, and V is the accumulator volume (Mayya 2004).

The effective time constant takes into account radon losses from both decay and leakage (i.e., back-diffusion). The rate of change of radon concentration inside the accumulator is determined by taking the derivative of with respect to time. When the measurement time is short, dC/dt for the theoretical and actual curves are equal, meaning that losses due to back-diffusion are insignificant. At t = 0 the increase in radon concentration is linear and given by (Mayya 2004)

$$\frac{dC(t)}{dt} = \frac{FA}{V} \qquad \text{(Equation 2)}$$

Thus, for a short accumulation time, the undisturbed radon exhalation rate can be calculated by Equation 2. The time at which dC/dt for the theoretical curve does not equal that of the actual curve will be dependent on the magnitude of the exhalation rate.

The Sun Nuclear Model 1029 radon monitor will measure radon concentration every half-hour. An example accumulation curve for a 24 hour measurement period is shown in Figure A.2. Based on the curve in Figure A.2, an accumulation time of three hours or less would provide certainty that back-diffusion losses are not significant. The data points collected within the first three hours show a linear relationship and can be fitted using linear regression. Origin Pro 8 was used to develop a linear regression model of the increase in radon concentration inside of the accumulator; up to the first six data points were used as inputs of the model. The model had the form of y = m*x + b, where m is equivalent to the rate of change of radon concentration.

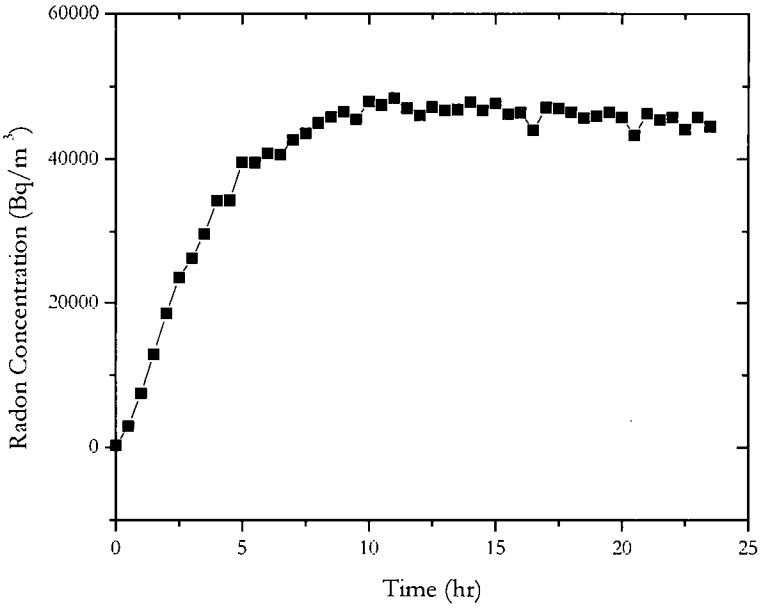

Figure A.2. Radon Concentration Inside the Model 1029 Accumulator

APPENDIX B
TABLES

Table B-1. Radon Exhalation Measurements Made With the Model 1029 Under Normal Environmental Conditions					
Measurement Date	**Temperature (°C)**	**Pressure (hPa)**	**Relative Humidity (%)**	**dC/dt[a] (pCi/s)**	**Exhalation Rate (pCi/m² s)**
07/26/2012	28.5	991.6	66.7	2.39 ± 0.49	8.44 ± 3.39
07/27/2012	29.3	992.6	61.5	1.20 ± 0.20	4.24 ± 1.41
07/31/2012	26.9	992.0	64.0	1.45 ± 0.03	5.12 ± 0.21
08/01/2012	26.0	992.9	62.2	1.31 ± 0.00	4.65 ± 0.02
08/06/2012	24.5	998.1	66.2	3.31 ± 0.21	11.7 ± 1.4
08/07/2012	25.3	994.8	66.3	1.22 ± 0.08	4.32 ± 0.54
08/08/2012	26.4	994.7	64.6	0.979 ± 0.06	3.46 ± 0.38
08/09/2012	24.4	992.3	64.5	0.954 ± 0.19	3.37 ± 1.29
08/13/2012	23.5	995.0	56.0	0.971 ± 0.00	3.43 ± 0.00
08/15/2012	21.9	991.8	62.8	0.966 ± 0.02	3.41 ± 0.13
08/16/2012	21.6	995.1	61.5	0.858 ± 0.19	3.03 ± 1.28
08/20/2012	20.9	991.9	59.8	1.26 ± 0.09	4.44 ± 0.59
08/21/2012	19.7	994.7	55.2	1.01 ± 0.10	3.57 ± 0.67
08/22/2012	20.4	997.2	55.8	0.97 ± 0.15	3.42 ± 1.03
08/23/2012	20.6	998.0	56.1	1.01 ± 0.18	3.57 ± 1.25
09/05/2012	24.5	991.5	64.6	1.01 ± 0.18	3.57 ± 1.27
09/06/2012	21.9	993.2	62.8	1.12 ± 0.13	3.95 ± 0.87
09/10/2012	26.4	997.1	48.6	0.62 ± 0.15	2.18 ± 1.02
09/11/2012	18.9	1000.7	55.6	0.71 ± 0.04	2.52 ± 0.29
09/17/2012	21.6	993.7	60.0	0.92 ± 0.16	3.24 ± 1.10
09/17/2012	21.4	989.9	63.9	1.71 ± 0.05	6.04 ± 0.35
09/19/2012	16.5	996.0	56.4	1.14 ± 0.07	4.03 ± 0.48

[a]dC/dt = rate of change of radon concentration inside the accumulator with respect to time

DISPOSAL OF URANIUM TAILINGS AS PASTE

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ABSTRACT

Disposal of mine tailings as a paste incorporating Portland cement can provide environmental benefits by reducing contaminant movement. A proposal to use the method to dispose of uranium ore tailings at the Jabiluka mine in northern Australia is being investigated. The mining lease is within the boundaries of Kakadu National Park, a designated World Heritage Area, so particular care is being taken to ensure that groundwater in the park is not deleteriously affected by tailings disposal. No description of a comparable uranium tailings disposal project has been found in existing literature.

This paper discusses paste preparation, paste properties and the benefits of using paste technology. The effects of several factors which control paste properties and may affect subsequent leaching of contaminants from the paste mass are discussed in detail. They include tailings properties, type of cement, tailings water composition and emplacement methods. Chemical and physical aspects related to forming a stable tailings deposit which will immobilise contaminants to the maximum extent are emphasised.

INTRODUCTION

Disposal of mine tailings as a paste after partial de-watering and addition of a small percentage of ordinary Portland cement is being regarded increasingly as good practice in the mining industry. The method has the potential to bind possible groundwater contaminants into a solid mass and thus reduce adverse effects on the environment. The paste can be disposed of in surface or underground repositories. If paste is deposited in worked out stopes, it can be given sufficient strength when cured to support further mining.

There is a current proposal to use the method to dispose of tailings at the Jabiluka uranium mine which is in the early stages of development in the Northern Territory, Australia. The mining company, Energy Resources of Australia (ERA), would prefer to process Jabiluka ore at the existing open pit Ranger mine, some twenty kilometres distant. Tailings would be stored there in the open pit with Ranger tailings. However, problems obtaining approvals from the indigenous people to transport ore through territory under their control have forced the company to consider using a processing facility on the Jabiluka mining lease which is surrounded by, but does not form part of, Kakadu National Park, a World Heritage Area. ERA proposes to store the tailings from a processing plant at Jabiluka as a paste after adding Portland cement.

An earlier proposal involved backfilling stopes with about half the tailings paste and disposing of the remainder in two specially constructed deep open pits in the Kombolgie sandstone formation which overlies the ore-containing schist. However, a preliminary examination of possible sites for the pits indicated deep weathering and relatively high permeability of the sandstone to depths up to 50m. Consequently ERA revised the tailings disposal plan to replace the pits with specially constructed underground silos.

Current approvals from the Australian Government require tailings in excess of those which can be accommodated in mine workings to be stored in deep underground repositories. Comprehensive investigations of paste properties are being undertaken by ERA, together with environmental studies including an examination of the possible impact of tailings disposal on the groundwater and surface water environment of Kakadu National Park. Regulating authorities have also commissioned studies of the potential impact of the mine and tailings on the park environment.

This paper discusses factors specifically related to paste which incorporates low levels of radioactive elements, in particular uranium and radium, and other potential groundwater contaminants such as magnesium sulfate and manganese. The last two can occur in relatively high concentrations in pore water in tailings as a result of recycling water in the uranium extraction process. Physical and chemical requirements related to paste setting, strength, plasticity and permeability which will minimise contaminant pickup by groundwater will be addressed.

Although ERA's current proposal for disposal of tailings at Jabiluka involves only underground storage of paste, disposal both underground and in open pits is covered in this paper for the sake of generality

A search of the literature and enquiries addressed to specialists involved in mining and hydrogeology have not revealed any case where the paste method has been used in the disposal of tailings produced during the production of uranium oxide from uranium ore. It is hoped that discussion of this paper will provide information on other investigations into the disposal of uranium ore tailings after the addition of cement to form a setting paste.

REVIEW OF PASTE TECHNOLOGY

Paste technology has been used relatively widely in underground backfilling applications because of its economic and practical advantages over hydraulic sandfill and cemented rockfill (Millette et al., 1998). A similar technology has now been developed (and continues to be refined) for treatment and disposal of tailings both underground and at the surface (Brackebusch and Shillabeer, 1998).

Pastes are defined as dense, viscous mixtures of tailings and water which, unlike slurries, do not segregate when allowed to rest (Cincilla et al., 1997). The most important distinguishing characteristic is the grain size distribution of the tailings solids. Empirical data indicate that to form a paste, tailings must contain at least 15% (by weight) of fine solids that pass a 20 µm filter. This fine fraction enables the paste to flow through a pipe without segregating and also increases the water retention capacity because of the ability of the colloidal fraction to retain large volumes of water at their surface. Paste produces a plug flow when transported through a pipeline. Furthermore, because of its non-segregating behaviour, pipe transport is not limited by a "critical" flow velocity, as is the case for slurry transport (Verburg, 1997). Materials without ultrafine particles will not form pastes.

Paste has a low permeability because of the presence of the ultrafine particles which fill voids between the larger particles. Low permeability limits water and air flow through the paste, thus limiting oxidation of sulfides and leaching of metals

The pressure gradient required for pipeline transportation of paste is much higher than that required for dilute slurries Much more pumping energy is therefore required to deliver the paste from the mineral processing plant to the tailings deposit. Practical pumping distances range up to three kilometres (Brackebusch and Shillabeer, 1998). In the case of underground mines with surface treatment facilities, gravity can supply most or all of the pressure head required to deliver paste to backfill mine workings or other underground repositories.

Proponents of the paste disposal method claim significant environmental benefits including elimination of surface impoundment of waste liquids, reduction in leachate generation due to high water incorporation capacity, the ability to "engineer" a paste suited to the waste which will enhance environmental benefits, increased rates of filling (rise) compared to slurry disposal and enhanced flexibility in placement practice (Verburg, 1997; Cincilla et al., 1998).

Paste additives

A basic tailings paste consists of tailings and water. Additives, such as Portland cement, are commonly incorporated into tailings pastes to increase strength and durability. Published data for pastes with various percentages of cement addition (Bodi et al., 1996) indicate that uniaxial compressive strengths range from 250 kPa to more than 2,100 kPa for Portland cement percentages of 4 to 16%, with curing times between 7 and 28 days. Cincilla et al. (1997) indicate that cement additions as low as 1% can produce a significant increase in strength. Unconfined compressive strength (UCS) results for 7 day cured full plant tailings yielded UCS values of approximately 70, 150 and 220 kPa for 0, 1 and 3% Portland cement additions.

Choice of additives

Ordinary Portland cement (OPC) has been widely used as a binding agent for tailings pastes and is considered to lead to reduced permeability of the paste, entrapment of contaminants through microencapsulation and generation of neutral to alkaline conditions which generally favour metal contaminant fixation (Verburg, 1997). Other additives, such as fly ash and ground furnace slags, have been used, often in combination with OPC (Chen et al., 1998). These waste products have the advantage of lower cost compared to OPC and alternative binders with even higher water retention capacities than OPC (Sun et al., 1998).

Glasser (1997) notes that the introduction of fly ash and slag does not dramatically affect the paste porosity but does

reduce pore connectivity, with the result that well-cured blends may achieve lower permeabilities (< 10^{-12} m/s). This process, known as pore refinement, has been explored by a wide range of methods (Hooton, 1986). It should be recognised that pore refinement in cement and its blends occurs relatively slowly. With good curing, significant decreases in porosity and permeability could be expected over the first 6-12 months after emplacement. However, the extent to which this refinement process would occur in cemented tailings would probably be limited by the low levels of cement addition proposed.

The addition of 1 to 4% by weight of cement is proposed by ERA for paste made from Jabiluka tailings. The percentage would depend on the engineering requirements (particularly strength) of the product. Significant further testing and optimisation of the nature and extent of addition of binding agent(s) will be required prior to final implementation. Some of this work is already being carried out. A 1% addition of cement would appear to be low, particularly in view of the potential for consumption of some of the cement constituents in neutralising the highly acidic process liquors (though lime will be added specifically for this purpose, thereby reducing the demand on cement alkalinity).

De-watering tailings

ERA plans to de-water tailings using a belt filter (ERA, 1998). The solids content achievable through such a process is uncertain, but a "toothpaste consistency" with solids content in the 70-85% range would appear desirable (Brackebusch and Shillabeer, 1998). Some problems can be envisaged in achieving such a solids content, particularly given the presence of significant concentrations of iron oxyhydroxide and siliceous material that will undoubtedly form on neutralisation of the tailings through lime addition. These materials will occur in polymeric, gelatinous form and may lead to significant fouling of the belt filter through formation of a relatively impervious cake.

Significant effort in optimising de-watering procedures is considered essential. Aspects which should be considered are: the pH dependence of belt filter de-watering efficiency; methods to prevent belt filter fouling by generated gelatinous materials (eg through selective use of synthetic polymeric conditioning agents, electro-osmotic enhancement of belt filtration, etc); alternative de-watering methods; the possibility of "staging" the de-watering process with subsequent recombination of the solid phases.

Incorporation of additives into the paste

Effective mixing of cement and de-watered tailings paste will be necessary to ensure generation of a homogeneous product. ERA (1998) mention that a "repulping" of de-watered filter cake and cement will be used to generate a cemented product. More detailed consideration of the mode of mixing may be necessary with consideration given to high-shear colloidal mixers (Reschke, 1998) and other related approaches.

Mode of action of added cement

The mode of action of OPC in the "curing" of tailings paste is considered to be identical to that in normal concrete. That is, hydration of the major components of OPC, namely tricalcium silicate ($3CaO{\cdot}SiO_2$ or C_3S), dicalcium silicate ($2CaO{\cdot}SiO_2$ or C_2S), tricalcium aluminate ($3CaO{\cdot}Al_2O_3$ or C_3A) and tetracalcium aluminoferrate ($4CaO{\cdot}Al_2O_3{\cdot}Fe_2O_3$ or C_4AF) leads to formation of a strong, interconnected solid mass which would be expected to have low permeability, particularly given the relatively fine nature of the constituent solids (Neville and Brooks, 1987). It should be noted however that the presence of significant amounts of high water retention solids, particularly the colloidal iron, manganese and silicon oxides, could result in a modification of the established curing process.

Impact of tailings water composition on cement behaviour

A significant factor which must be addressed is the likely impact of tailings water composition on the strength and porosity of the resultant cemented mass. Both sulfate and magnesium are expected to be present at relatively high concentrations in the tailings water yet both are recognised to retard the setting time and reduce the strength of normal concrete (Neville and Brooks, 1987; Kumar and Rao, 1994). Concerns related to the effect of sulfate on the long term integrity of cemented tailings paste have been expressed by Ouellet et al. (1998).

Cements which are resistant to sulfate attack are commercially available. Type SR cement is reported to be able to withstand sulfate attack at concentrations up to 5% when expressed as SO_3 (approximately 50,000 mg/l) though this relates to the ability of concrete to withstand "external" attack. The rate of deterioration might be expected to be somewhat more rapid when the sulfate is present in the mix water (as it will be in the case of tailings paste).

While precise concentrations of ions in the Jabiluka tailings are uncertain, the major ion composition of process liquors from the nearby Ranger mine provide a guide to what might be expected at Jabiluka (Ranger and Jabiluka ore occur in the same form in the same host rock formation and similar processing is envisaged). Sulfate concentrations approaching 50,000 mg/l are present in process waters and similar concentrations would be expected in tailings waters prior to neutralisation. Addition of lime will result in a pH increase (a pH of 5 is proposed for Jabiluka) and some gypsum ($CaSO_4$) precipitation would be expected. Sulfate concentrations in Ranger tailings waters are typically of the order of 20,000 mg/l. On this basis, it could be expected that more than half of the sulfate would be removed from solution at Jabiluka, though precipitation may result in calcium sulfate accumulation in the solid phase to which cement is being added.

Kumar and Rao (1994) report that the deleterious effects of sulfate peak at 3000 - 4000 mg/l sulfate after which the impact on setting time and strength is not as severe. Indeed, the loss in compressive strength due to the presence of sulfate does not appear to exceed 25% of that observed in the absence of sulfate. While such reductions in concrete strength might be

considered critical in the construction industry, the magnitude of such changes would not appear sufficient to seriously limit the use of cement binder for tailings paste, although such effects do flag the need to comprehensively examine the impact of tailings water chemistry on cemented paste behaviour.

While detailed investigation of the effect of tailings water composition on the strength and integrity of the resultant "cemented tailings" must be implemented, consideration should also be given to other means of overcoming this problem. Options include minimisation of the use of sulfate in the ore processing and removal of sulfate (and possibly magnesium) from the tailings water prior to paste formation and cement addition.

The first option is non-trivial and would require a re-assessment of the process used for extracting uranium. The second option is also problematic in that contaminants would need to be removed prior to de-watering and would need to be segregated in some way from other waste solids (which are to be disposed of in paste form). However, neither option should be discounted. The issue of treatment of tailings water prior to reuse in the process (a necessity in the case of Jabiluka because of the zero surface water release policy) demands particular attention from the wider perspective of avoiding problems in the process due to the re-use of waters containing significant levels of contaminants. Not only might scale formation due to precipitation of calcium and/or magnesium solids create problems, but the presence of gelatinous iron and silica polymeric materials could well cause serious problems in solvent extraction and solid-liquid separation steps. Removal of at least a portion of these materials would seem essential given the concentration build-up that would be expected given the requirement of zero contaminant release.

Given the apparent detrimental effect of sulfate on cement integrity, it is interesting to note that recent work has shown that calcined gypsum can be used in place of OPC as a tailings paste binder. Thus, Petrolito et al. (1998) have shown that compressive strengths equivalent to that achieved with OPC can be obtained through use of 2.5 to 4 times the corresponding amount of cement. Given the abundance of calcium sulfate in the tailings, use of an alternative binder of this form has considerable attraction. Obviously, to achieve the binding properties required, calcination would be necessary. Such a process would require the separation of precipitated gypsum from the tailings solids to enable calcining but the returns achievable may justify the considerable development work that would appear necessary to facilitate such an approach.

Emplacement and curing

Paste could be placed in and cured in de-watered repositories or under water.

In the case of disposal in open pits, sub-aqueous deposition would be the most likely since special provision would have to be made to pump rainwater or any liquor bleeding from the paste away to some liquid storage facility. Underground mine workings and underground silos could be backfilled under water, or in the dry if appropriate drainage and pumping were maintained.

Free fall of the paste either above or below a water surface would incur the risk of segregation. This could lead to both chemical and physical inhomogeneity of the deposited paste. The former could result in zones of concentration with increased solubility and leaching of contaminants while the latter could result in more permeable zones of coarse material which would allow groundwater easier passage through the tailings deposit. Both effects would be deleterious in relation to the movement of contaminants from the site. Use of a movable tremie pipe to discharge paste below the surface of previously deposited material and distribute it evenly would be advantageous.

Uneven settlement and shrinkage of the tailings may be sufficient to cause cracking of the tailings mass and thus higher permeability. This is more likely to occur in backfilled mine workings than in the vertical cylindrical silos proposed for Jabiluka because of the irregular shape of the former which will cause stress concentrations during curing. This potential problem needs to be addressed when strength and deformability data are available from laboratory testing.

Another potential problem in the case of backfilling mine workings is leaving voids, particularly at roof level, to form channels through which groundwater could flow freely. These must be avoided to restrict contaminant movement.

SUITABILITY OF JABILUKA ORE FOR PASTE FORMATION

Golder Associates made an assessment of the paste forming potential of the Jabiluka ore using diamond drill core (Golder Associates, 1997). The core was processed in a laboratory to form tailings which would represent those to be produced by the proposed mine. Over 30% of the tailings was found to be less than 20 μm in size, indicating that the tailings would be suitable for paste formation. The results of rheological tests indicated that the properties of trial pastes made from tailings and water (i.e. without addition of cement) were "excellent", with low yield stress and good water retention. The little water that bled from the paste would probably be taken up by the cement which will be added to the tailings under current proposals.

ERA has commissioned consultants to perform a range of tests on pastes containing Portland cement. The results will be available in the near future.

CONTAMINANT MOBILITY

From the environmental viewpoint, the most important requirement of tailings disposal is minimisation of movement of contaminants from the site. It is assumed that erosion of the tailings by the forces of nature will be prevented for an appropriate period by burial at a sufficient depth under a cover which will remain in place. However, even though the tailings are physically immobilised, contaminants can still move from the site in gaseous form or dissolved in groundwater.

Radon gas produced by the radioactive decay of radium is a potential atmospheric contaminant. Its movement is redu-

ced, and dispersion improved, by low permeability of the tailings mass and cover.

Prevention of leaching of contaminants from the tailings mass can be considered as the primary barrier to groundwater contamination. Low permeability of the surrounding rock and adsorption of contaminants such as uranium within the rock provide a secondary barrier. The distances contaminants will move, and concentrations of contaminants in groundwater near the tailings repositories, will depend on the efficacy of both of these barriers and the magnitudes of hydraulic gradients in the groundwater flow system.

The potential of paste technology to improve the physical properties of the primary barrier have been discussed above. Possible problems related to chemistry have also been discussed. It is essential that adequate investigation of both physical and chemical properties of pastes affecting stability and leaching be carried out in particular cases. This data must then be used with appropriate groundwater flow and contaminant transport analyses to predict environmental effects.

Effect of cement addition on contaminant leaching

The addition of cement to tailings paste is likely to have an overall positive effect on contaminant immobilisation. The alkaline conditions that are likely to result from lime and cement addition to the tailings is expected to assist in "fixation" of a range of contaminants either through formation of insoluble oxide/hydroxide forms or through enhanced adsorption to solid phases (particularly the high surface area, amorphous iron, manganese and silicon oxides that will form on pH increase). However, uranium may be mobilised under such conditions. The affinity of uranium for carbonate anions is sufficiently strong for U(VI) to be made soluble at pH values above about 8 where the concentration of carbonate in solution is sufficient to dominate the speciation of U(VI) (Waite et al., 1992; Waite et al., 1994). While this issue is worth noting, a number of factors may counter the possible dissolution of U(VI) at high pH. These are:

- A considerable amount of silicate will be present which may stabilise the uranyl ion either in insoluble uranyl silicates or in surface-bound U(VI)-silica ternary complexes,
- The possibility of formation of insoluble magnesium-uranium sulfates, magnesium-uranium carbonates, calcium-uranium carbonates or calcium-magnesium-uranium compounds exists (Wanner and Forest, 1992; Glasser, 1997). Such solids have been identified as apparently controlling uranium solubility in high pH, high sulfate cement pore waters in northern Jordan (Linklater, et al., 1996),
- Much of the deposited tailings may become anoxic and exhibit reducing conditions as a result, in part, of the inability of oxygen to diffuse into the relatively impermeable, sub-aqueous matrix. Under such conditions, U(VI) would be expected to undergo redox transformation to the U(IV) state where it would be expected to form highly insoluble oxides. While considerable variability has been reported in the solubility products of "amorphous" or "hydrated" forms of UO_2, these solids would be expected to be highly insoluble over a relatively wide pH range (Wanner and Forest, 1992).

Approximately 5% of the uranium in the ore will remain in the tailings. This uranium has survived the harsh physical and chemical treatment applied to the ore to extract as much of the uranium as possible. Consequently only a small proportion of the remaining uranium might be easily accessible to alkaline solutions which could possibly mobilise it and carry it into the groundwater.

Long term stability and contaminant containment

With regard to the ability of cemented tailings to immobilise contaminants, the scientific literature is not definitive. While it might be expected that oxyanions of elements such as arsenic, selenium and chromium would exhibit limited sorptive capacity to surface sites of tailings constituents (Dzombak and Morel, 1990; Glasser, 1997), the evidence suggests that these anions are stabilised to relatively low solution concentrations at high pH, presumably as a result of formation of (often ill-defined) mineral phases (de Groot et al., 1989). The possibility of U(VI) mobilisation as a result of the formation of highly soluble uranyl carbonates has also been mentioned but the likely formation of uranyl silicate and/or calcium-uranium precipitates is expected to mitigate such an effect. Notwithstanding these arguments of likely contaminant immobilisation, comprehensive leaching studies of contaminant stability, particularly as a function of pH and major ion tailings water composition, should be undertaken.

Glasser (1997) points out that generation of gases such as CO_2 and CH_4, mainly as a result of microbiological activity, could lead to cracking and physical deterioration of the matrix. Carbon sources for such activity are likely to be limited however and the potentially high pH conditions may limit microbiological activity. Lange et al. (1996) also note that carbonation of cement-solidified hazardous wastes appears to lead to a stronger rather than weaker solid matrix with enhanced metals retaining ability.

A substantial literature exists on use of cement solidification and stabilisation of hazardous materials, including radioactive wastes (see, for example, Connor, 1990; Glasser, 1997). While the proportions of cement being added are typically somewhat higher than those proposed for tailings pastes, many of the issues raised with regard to fixation of tailings contaminants have been considered to some extent. Close attention to this literature should be maintained as comprehensive test programs are implemented.

ACKNOWLEDGMENT

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CEMENTED TAILINGS BACKFILL – IT'S BETTER, NOW PROVE IT!

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ABSTRACT

A promising and increasingly popular tailings management strategy is to place cemented tailings underground as backfill. The placement of cemented tailings results in enhanced geotechnical stability and a purportedly more geochemically stable tailings form with lower leaching potential. Conventional subaerial tailings management can negatively affect water quality if weathering causes acid rock drainage and metal leaching (ARD/ML) to occur, whereas cemented tailings can limit leaching via porosity and permeability reductions and contribute alkalinity to limit the potential for ARD/ML. Cemented tailings backfill appears to be better, but how can this advantage be proven?

Currently, cemented tailings backfill is utilized at mining operations internationally, but there is limited guidance on performing geochemical characterization and associated evaluation of the potential impacts to water quality. As a result, various approaches to simulating the leaching behavior of cemented backfill have been utilized, including some methods that are unlikely to represent weathering under site-relevant conditions. American Society for Testing and Materials (ASTM) Standard Test Method C1308-08 is a diffusion testing method initially developed to assess constituent release rates from solid nuclear waste forms. ASTM C1308-08 uses intact cylinders that more closely represent actual backfill than methods that require crushing or size reduction. It is widely believed that leaching from actual cemented tailings is controlled by diffusion through small pores that exhibit limited exposed surface area, making diffusion testing particularly applicable to cemented tailings placement.

BACKGROUND

Backfill can be grouped into two general categories including uncemented backfill, such as hydraulic and paste fills, and cemented backfill, which includes binding agents such as Portland cement or a blend of Portland cement with another pozzolan such as fly ash, gypsum or blast furnace slag (ACG, 2005). Local and regional stability is improved by backfilling, thereby increasing the safety and efficiency of mining operations. For example, cemented backfill allows the removal of ore pillars when mining by room and pillar methods while also preventing heading collapse and subsidence. The inclusion of tailings has the added advantage of reducing or eliminating the surface disturbance associated with tailings management.

The use of cemented tailings backfill has been employed globally at numerous mine operations, as demonstrated by the following project examples:

- A cemented paste backfill system has been in place since late 1997 at the BHP Cannington underground silver-lead-zinc mine in Northwest Queensland, Australia (Rankine et al., 2001).
- The Stratoni Operations in northeastern Greece, including the Madem Lakkos (ML) and Mavres Petres (MP) lead, zinc and silver mines have used cemented paste since the late 1990s or before (Newman, 2001; European Goldfields, 2010).
- The Higginsville gold operation, located 150 km south of Kalgoorlie in Western Australia, has a cemented paste plant that has been operational since 2009, allowing stopes to be mined (Avoca Resources Limited, 2009;Alacer Gold Corp., 2012).
- The Zinkgruvan zinc, lead, and silver mine in Sweden includes cemented paste backfill as part of the tailings management since 2001, with approximately 50% of the tailings being backfilled (Moore, 2012a).
- A paste plant was recently commissioned at the Porgera gold mine in Papua New Guinea (2010 to 2011) and is producing cemented paste backfill to manage approximately 10% of the project tailings (Putzmeister, 2012).
- The Olympic Dam uranium and coppermine has used cemented paste backfill to manage a portion of the project tailings and waste rock (Grice, 1998).
- Approximately 60% of the tailings from the Langlois zinc and copper mine in northwestern Québec were used in paste backfill prior to temporary suspension of mining activities (Breakwater Resources Ltd., 2010).
- The Neves Corvo copper and zinc mine in Portugal has used four different backfill systems depending on the mining method, including hydraulic fill, cemented rockfill, slinger belt cemented rockfill and paste (Moore, 2012b).
- The BarrickGoldstrike mine will be the first operation in Nevada to use cemented tailings backfill once the plant is operational in January 2013, following a three month commissioning period (Elko Daily Free Press, 2012).

The stability aspects of various backfill strategies are well understood and have been the subject of extensive research, whereas the environmental aspects have received less attention (ACG, 2005; Antonov, 2009). It is generally accepted by the industry that backfilling reduces environmental impacts because of the reduction in oxidation and leaching compared to convention tailings management strategies. However, a Mine Environment Neutral Drainage (MEND) Program review of approaches used to characterize cemented and uncemented tailings backfill ("MEND report") found that the available information pertaining to the environmental aspects was minimal, with the majority of the research being focused on the physical characterization with the objectives of meeting the minimum structural requirements (Mehling Environmental Management, Inc., 2006).

CHARACTERIZATION PROGRAMS

Geochemical characterization of mine materials such as cemented tailings backfill typically includes testing using a variety of methods such as:

- Acid-base accounting;
- Total elemental analyses;
- Mineralogical characterization;
- Static leaching testing; and
- Kinetic testing.

In addition to the MEND report, there are a number of guidance documents that practitioners can reference when developing a detailed characterization program for mine materials including, for example:

- Prediction Manual of Drainage Chemistry from Sulphidic Geologic Materials (Price, 2009).
- The International Network for Acid Prevention (INAP) Global Acid Rock Drainage Guide (GARD Guide) (INAP, 2009).
- Managing Acid and Metalliferous Drainage (Department of Industry, Tourism and Resources, 2007).

Although these documents are excellent references for understanding the available test methods and other environmental aspects of mining, ASTM C1308-08, which was originally approved in 1995, has only recently been used for mine backfill testing.

Standardized and more innovative approaches to static leaching and kinetic testing have been employed when characterizing cemented tailings backfill. Conventional water leaching methods, such as the United States (US) Environmental Protection Agency (EPA) Method 1312 – Synthetic Precipitation Leaching Procedure (SPLP) (EPA 1312) and the Modified British Columbia Special Waste Extraction Procedure (SWEP) (Price, 2009), and humidity cell testing (ASTM D5744-96) require a reduction of sample particle size through crushing and/or grinding (e.g., to less than 10 millimeters [mm] as per EPA 1312). This reduction of particle size results in high surface area to solution volume test conditions, as well as particles with high surface energies more prone to dissolution. Therefore, resulting leachate has distinctly different water quality signatures than leachate produced using larger particle size samples. To address this issue, some practitioners have adapted the methods by using molded cubes ranging in size from less than 1 centimeter (cm) to 3 cm rather than crushing, using multiple extract static water leach tests, and customized subaqueous column tests (Mehling Environmental Management, Inc., 2006). In September 2012, EPA published methods as part of SW-846 (Test Methods for Evaluating Solid Waste, Physical/Chemical Method (EPA Method 1313 and 1316) directed at coal combustion products, which address perceived shortcomings in available static leaching methods such as EPA 1312.These updated methods specify evaluating constituent release under various different conditions, including pHand solid to solution ratios. Of the methods used for characterizing cemented paste backfill leachate, EPA concluded that subaqueous columns and multiple leach static testing appear to be best suited for simulating post-closure conditions and have some similarities to the passive diffusion testing.

The application of ASTM C1308-08 to cemented backfill can arguably replace, or at a minimum supplement, more traditionally used static leaching and kinetic testing methods.

METHODOLOGY

The following subsections address the initial development of ASTM C1308-08 to assess constituent release rates from solid nuclear waste and an overview of the methodology as applied to cemented tailings backfill.

Initial Applications

Solidification of radioactive waste through vitrification in a glassy matrix, or through addition of grout or cement to form a solid monolith, has been used since the 1980s to immobilize radionuclides and to isolate them from the environment (USNRC, 1991). The US Code of Federal Regulations (CFR) provides strict guidance for near-surface land disposal of radioactive waste in 10 CFR 61, Licensing Requirements for Land Disposal of Radioactive Waste. Part of these requirements include demonstrating that the wastes are structurally stable, maintain physical dimensions under loading, and do not leach radio nuclides that result in excessive exposure to the public. Leach testing of cement waste forms, to meet the requirements of 10 CFR 61, was initially performed using ANSI/ANS 16.1, “Measurement of the Leachability of Solidified Low-Level Radioactive Wastes by a Short-Term Test Procedure.” This test involved a sample of the solidified waste form placed in deionized water, with the water replaced according to a prescribed schedule. The US Department of Energy and utilities regulated by the Nuclear Regulatory Commission have recently used ASTM C1308-08 to demonstrate compliance with these requirements (e.g. Sams et al., 2011). In addition, this method has recently been used to demonstrate compliance with waste acceptance criteria for liquid low- and high-activity radioactive wastes after solidification for disposal at the Hanford Reservation (solidification includes combination with fly ash and blast furnace slag, and alkali aluminosilicates) (Mattigod et al., 2011). The capability of ASTM C1308-08 to provide data to satisfy regulatory requirements for radioactive waste disposal indicates that it is a robust method already accepted by US State and Federal regulators.

Recent Applications

The use of ASTM C1308-08 to characterize mine backfill materials was born out of necessity due to the lack of appropriate characterization tools to simulate conditions that would be encountered in the field.

BarrickGoldstrike Mines, Inc. (Goldstrike) is the first operator that made public the use of passive diffusion following ASTM C1308-08 to characterize cemented tailings backfill. Goldstrike proposed the method to the Nevada Department of Environmental Protection (NDEP) to support permitting of the currently permitted backfill recipe and additional recipes (BarrickGoldstrike Mines, 2010). Passive diffusion testing was also used by Nevada Copper Corporation to characterize leachate associated with cemented tailings backfill for the Pumpkin Hollow Project (Nevada Copper Corporation, 2012). Western Environmental Testing Laboratory (Wetlab) is regularly testing cemented backfill samples following ASTM C1308-08 (Nick Ross, personal communication, October 31, 2012). Wetlab developed a Standard Operating Procedure for the testing to address the demand and maintain acceptable quality (Wetlab 2012).

Method Overview

ASTM C1308-08 utilizes solid sample cylinders immersed in leaching solution (either synthetic or site groundwater), with the solution volumes replaced sequentially after a given period of time (11 or more consecutive days). Each volume is analyzed for constituents of interest, and through the replacement of each volume of solution, a leach profile can be developed. After this analysis is complete, diffusion coefficients can be calculated for application in numerical models, which are used to simulate the backfill environment. Predictive modeling is then performed to evaluate expected concentrations of constituents over time.

Cemented tailings, backfill testing is typically conducted at 20 degrees Celsius (°C)and assumes the effect of temperature on leaching behavior is known. When the effect of temperature is unknown, the tests should be conducted at three discrete temperatures, as detailed in ASTM C1308-08.

Based on specific site conditions, the following modifications to ASTM C1308-08 may be appropriate:

- Modified leachant replacement schedules (e.g., extending the test interval to beyond 11 days, adding or canceling replacement intervals);
- Modified solution to solid ratio;
- Synthetic or site groundwater; and
- Carbon dioxide (CO_2) sparging.

The solution to solid ratio of 10:1 as specified by ASTM C1308-08 is a balance between providing adequate volume for analysis and minimizing leachant handling and disposal concerns. In 2010, Barrickspecified solution to solid ratios ranging from 1.9:1 to 27:1. Conducting tests over a range of solution to solid ratios provides a sensitivity analysis of leaching behavior to variable leachant exposure. Testing leaching behavior over a wide range of solution to solid ratios allows for a better understanding of leaching behavior under actual subsurface placement conditions.

Site conditions over the life of the mine should be carefully considered when developing a characterization program that utilizes ASTM C1308-08. For example, the use of Portland cement as a binder to consolidate and strengthen the backfill can result in highly alkaline water (pH greater than 10) under atmospheric partial pressure of carbon dioxide (PCO_2). This pH increase is due to the initial hydroxide alkalinity and subsequent formation of cement hydration products. Under these alkaline conditions, metalloids such as arsenic and antimony are likely to be more mobile. This information may prove useful for assessing operational water quality, but is not applicable to the post-closure conditions of a flooded mine with elevated

groundwater PCO_2 (typically 1 to 2% as a result of biogeochemical processes). In this post-closure scenario, diffusion testing using site groundwater that is maintained under the appropriate PCO_2, as determined from geochemical modeling, will provide CO_2 acidity that will offset some of the alkalinity and result in distinctly different and more representative post-closure leachate quality.

The physical and chemical representativeness of the material and leachant is paramount to obtain relevant and useful results. It follows that material specimens should be prepared following the same composition as on the full-scale system (Figure 1 and Figure 2). Diffusion test cylinders can easily be prepared using the recipe(s) that most closely represent the composition used for the paste production plant design. Depending on the project stage, it may be more efficient and cost-effective to have cylinders prepared for diffusion testing at the same time the backfill is being testing to meet the design parameters for viscosity and strength. Cemented tailings backfill samples typically have a 1:2 diameter to height ratio, such as 6 inch (in) x 12 in and 3 in x 6 in cylinders (Wetlab, 2012).A 6 in x 12 in cylinder requires approximately 4.5 liters of leachant to obtain 10 times the surface area of the cylinder, as detailed in ASTM C1308-08.

Samples can be subjected to diffusion testing immediately after preparation; however, a 28 day curing period will provide sufficient time to achieve 90% of the anticipated strength as illustrated by a typical strength-gain curve for cement (Smith, 2005).

Initial characterization of the material and leachant is essential to inform site-specific modifications to the method and to design an appropriate leachant analysis program, which may include routine chemistry, major ions, and dissolved metals. Additional parameters may be included based on project objectives, site data and regulatory requirements. Physical characterization may include grain size and material composition and distribution (i.e., tailings, waste rock, and pozzolans like Portland cement and fly ash).

Figure 1. Tailings backfill sample cylinder (courtesy of WETLAB, Sparks, NV).

CONCLUSIONS

Guidance related to performing geochemical characterization of cemented tailings backfill and associated evaluation of the potential impacts to water quality is limited. ASTM C1308-08 has potential to replace more traditionally used static leaching and kinetic testing methods, which may not adequately represent leachate quality associated with cemented tailings backfill. Similar to other laboratory test methods, ASTM C1308-08 provides imperfect simulations of storage conditions due to the inherent limitations of the laboratory scale and conditions. To increase the validity of results obtained using ASTM C1308-08, practitioners should take site-specific design parameters and conditions into consideration when setting up the testing program. The method is regularly used to demonstrate that the wastes are structurally stable, maintain physical dimensions under loading, and do not leach radionuclides that result in excessive exposure to the public as required by 10 CFR 61. Application of ASTM C1308-08 to test cemented tailings backfill is relatively new but the use of the method in Nevada to demonstrate that cemented tailings backfill will not negatively impact waters of the State suggests that the method has potential to be considered by companies and regulatory agencies in other states and countries.

Figure 2. Transferring cylinders (courtesy of WETLAB, Sparks, NV).

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RE: CCAT's Combined Comments on a Package of EPA and CDPHE Proposed Agency Actions Regarding Lincoln Park Superfund Site, Canon City, Colorado, and Cotter Uranium Mill Tailings

These comments are submitted on behalf of Colorado Citizens Against ToxicWaste, Inc. ("CCAT") to address three overlapping and intertwined agency actions involving the overlapping regulations at the Lincoln Park Superfund site and the Cotter Cañon City Milling Facility.

- Radioactive Materials License, Amendment 54
- Agreement Regarding Licensing and Remedial Requirements ("1988 CD/RAP Amendment")
- Administrative Settlement Agreement and Order on Consent for Remedial Investigation/Feasibility Study

Because each proposal depends on terms from the other, this unified set of comments is provided to CDPHE pursuant to its Radiation Control Act ("RCA") authority and EPA under its Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA" or Superfund) authority as well as EPA's direct authority and regulations promulgated under the Uranium Mill Tailings Radiation Control Act ("UMTRCA"). In addition to the specific procedures and substantive standards in the RCA, CERCLA, and UMTRCA, the proposed package of agency actions contravenes law and basic principles of agency decisionmaking and are therefore arbitrary, capricious, and contrary to the state and federal Administrative Procedure Acts. 5 U.S.C. §§ 701, et seq., C.R.S. §§ 24-5-101, et seq.

I. Regulatory and Site Background

The Lincoln Park Superfund site involves controversial but complete exposure pathways between the contamination source - the Cotter uranium milling wastes - and CCAT members who live in the Lincoln Park neighborhood near, downwind, and downgradient from the mill. The Cotter mill contains multiple unclosed byproduct material impoundments that are not subject to a current, valid RCA license. None of the impoundments have entered the closure phase, as no closure plan has been prepared or approved.

A natural resources damage suit brought by Colorado against Cotter resulted in a 1988 consent decree and remedial action plan (1988 CD/RAP) being entered over EPA and community objections. The 1988 CD/RAP purported to resolve some issues involving contamination and release of hazardous substances as between PRPs Colorado and Cotter. However, the judicially-approved CD/RAP has not been implemented faithfully and judicial approval has not been sought to update the CD/RAP, resulting in an ineffective CERCLA response and ongoing groundwater contamination at the site and in the Lincoln Park neighborhood.

UMTRCA and RCA require that uranium tailings closure costs are the sole responsibility of Cotter and that foreseeable closure and remediation costs must be covered by a current financial surety payable to Colorado in the case that Cotter is unwilling or unable to carry out closure. Based on the entirety of the administrative record for the site, including the historical documents submitted in comments by Meghan Belaski, Cotter has proven both unable and unwilling to conform with timely closure requirements. CCAT brought many of the same issues faced today to the attention of the Colorado Attorney General, EPA, and CDPHE in 2002/2003, as confirmed by Meghan Belaski's records, but little progress has been made in the past decade on addressing the leaking impoundments and ongoing groundwater contamination.

CERCLA contemplates clean-up paid by Potentially Responsible Parties ("PRP"), which includes contributors of waste to the site, current or former owners, and operators. The list of PRPs likely includes Cotter, General Atomics, Commonwealth Edison, the State of Colorado, the United States, and others. To date, it appears that CDPHE and EPA have based decisions on the false assumption that Cotter Corporation, an entity with no visible income from ongoing activities, is the only PRP at the site. EPA and CDPHE have both concealed the identities of PRPs from the public, with CDPHE's Assistant Attorney General asserting in open court that other Colorado agencies, not CDPHE, would shoulder the burden of Colorado's PRP liability.

An undetermined number of Cotter's tailings impoundments are actively receiving byproduct materials, including soils, mill demolition materials, and contaminated liquids that are being actively retained by a notoriously leaky pump-back system. Groundwater contamination is found throughout the mill site, extending outward into the Lincoln Park neighborhood through a variety of contamination vectors. No attention appears to have been given to the need for clean up of the documented mill tailings disposal that has occurred over the years directly into the deep coal mine shafts at the site. Neither EPA nor CDPHE has approved a plan for the closure and perpetual care of Cotter's uranium tailings. Instead, the tailings impoundments continue to leak and the groundwater remains contaminated, with no concrete plans or enforceable milestones required by state and federal laws.

The joint proposal, negotiated in secret by EPA/CDPHE/Cotter without input from the federally appointed Special Master, attempts to avoid an array of RCA, CERCLA and UMTRCA requirements and violations. The proposal, read as a package, contravenes the substantive and procedural requirements of duly adopted statutes and a complex regulatory scheme meant to protect the public from the mismanagement and delayed closure and final disposition of uranium mill tailings. For example, paragraph 2 of the CD/RAP Amendment unlawfully releases Cotter and Colorado from obligations imposed by the 1988 Consent Decree based on conflicts with the package presented for comments. This coordinated effort contradicts federal law and the terms of the Consent Decree itself, which require judicial approval of changes to the consent decree. *See e.g.* Section XXIII of the Consent Decree.

The package deal may appear convenient for CDPHE and EPA regulators faced with multiple violations and the licensee's vigorous opposition to necessary and costly closure and remediation requirements. The package deal may also appear to benefit potentially responsible parties (PRPs) Colorado and United States. However, the public interest is not served by putting Cotter in charge of a set of investigations, while simultaneously releasing Cotter from licensing requirements of RCA and EPA UMTRCA regulations and the 1988 CD/RAP. Cotter has a clear interest in minimizing and avoiding the costs of clean-up that must be borne by all PRPs, including those not yet publicly announced. The coordinated package of agreements serves as an unlawful amendment to existing law where EPA and CDPHE propose to abandon the public disclosure and hearing opportunities in the RCA and CERCLA in favor of a new CERCLA RI/FS process where only a public comment period after RI/FS and proposed or preferred remedies are identified.

The financial interests of Cotter (General Atomics), Colorado, United States, along with a long list of other operators, owners, arrangers, and contributors, appears to have driven an *ultra-vires* bureaucratic re-write of state and federal law as applied to the Cotter mill and associated contamination that extends into the Lincoln Park neighborhood. Although CDPHE, EPA and Cotter may perceive existing law as an obstacle, CERCLA, UMTRCA, RCA, 1988 CD/RAP and state/federal APAs provide important procedural and substantive requirements that cannot be revoked or contravened by a package of agreements between PRPs.

The settlement and agency actions under review, individually and together, are "inappropriate, improper, or inadequate" under controlling federal and state law, and cannot be finalized as proposed. 42 U.S.C. § 9622(i). The proposed settlement cannot be approved based on the scant information provided by EPA. *See Utah by Department of Health v. Kennecott Corp.*, 801 F. Supp. 553 at 572 (D. Utah 1992)(denying approval on the basis that proposed consent decree is "not just and fair or consistent with the purposes of CERCLA."). The interrelated license amendment and agreement between Cotter and CDPHE violates CERCLA standards, the 1988 CD/RAP, and state and federal law, including EPA's UMTRCA regulations applicable to Agreement State' regulation of radon emissions and groundwater contamination. 40 C.F.R. Part 192.

II. The EPA Settlement Agreement is Not in the Public Interest

A. Substantive Issues

CCAT adopts and joins the comments on all documents submitted by the Lincoln Park Community Advisory Group members.

B. Putting the Lead PRP in Charge of the Investigation is Not in the Public Interest

Although EPA has maintained a veil of secrecy around the identity of other corporate and governmental PRPs, there is no question that each of the parties to the RI/FS Settlement agreement are among the parties with liability that flows from contribution, arrangement, operation, and/or ownership interest in the Cotter site. Although relative financial contribution of each EPA-identified PRP cannot be confirmed due to EPA secrecy, the limited record indicates that Cotter and its current and past owners and operators will shoulder the burden of the CERCLA costs. Although UMTRCA and RCA require Cotter to shoulder all of the costs of

closing the mill and tailings, these laws contemplate that state and federal agencies will carry out the investigations and analysis.

The history of the site confirms that putting Cotter in charge of the RI/FS is not in the public interest. At every historical turn, Cotter has acted as an adversary to the community requests and has disputed information that confirms the poorly designed and constructed impoundments are ineffective at containing the tailings, temporarily or in perpetuity. Quality control has plagued the Cotter mill, with ongoing disputes over the quality of Cotter's ongoing monitoring and reporting. The disputes between CDPHE and Cotter over unreliable data gathering and methodologies confirm that Cotter's role in the RI/FS should be limited, not expanded as is proposed.

Ongoing spills related to the failing pumpback system are part of ongoing and potentially expanding groundwater contamination. The SCS dam and pumpback system is designed to intercept only a portion of the ongoing groundwater contamination plume and pump the contaminated liquids back into evaporation ponds and eventual disposal of the 11e2 byproduct material into one of the supposedly inactive, closed impoundments.

The low quality of Cotter's data gathering, narrow scope of analysis, advocacy against past investigations, and recent repeated failures of the pumpback system confirms that the public interest is not served by putting Cotter in charge of the RI/FS. After decades of delays and resistance, it is time to bring in a team of professional investigators that do not have a financial interest in the outcome of the RI/FS. There is no legal or practical reason such professionals cannot commence the RI/FS before determining whether Cotter/General Atomics will pay all expenses under RCA/UMTRCA full-cost recovery mandate, or whether other PRPs will contribute.

C. Requesting Comment on pre-signed Decision Documents Does Not Allow Informed, Meaningful Public Comment

EPA and CDPHE have not met their respective reasoned decisionmaking and public comment obligations where EPA and CDPHE have already entered into agreements with Cotter and the agencies have not provided the necessary rationale for taking the proposed agency action. CERCLA settlements require meaningful public comment, and submittal to the district court with ongoing CERCLA jurisdiction at Lincoln Park pursuant to the 1988 CD/RAP. 42 U.S.C. § 9622(i). Similarly, the proposed Colorado licensing action requires an application, agency environmental documentation, and opportunity for public hearing. 6 CCR 1007-1 Part 18. ("The requirements of this part apply to byproduct material that is located at a site where milling operations are no longer active […]. Id. at 18.1.3.). Cotter did not file a Part 18 application or environmental report.

CDPHE did post a document titled "Decision Analysis for Amendment 54 of Cotter License, 369-01." However, CDPHE provided no application or Environmental Impact Analysis, and provided no notice of an opportunity to request a hearing on the license application. The Decision Analysis contains a series of snippets and conclusory statements, none of which are supported by any data or analysis of the conditions at the site or the consequences of the proposed amendments. There is no question CDPHE ignored Part 18 of its own regulations.

The Federal Register notice is also devoid of information necessary to determine whether the settlement package is reasonable. 79 Fed. Reg. 50908. Relevant CERCLA factors involve

whether the decree is in the public interest and upholds the objectives of CERCLA, whether the decree is technically adequate to accomplish the goal of cleaning the environment, and whether the agreement reflects the relative strength or weaknesses of the settling party's position. *See United States v. Kerr-McGee Corp*., 2008 WL 863975, at *5 (D. Colo. Mar. 26, 2008); *WildEarth Guardians*, 2011 WL 4485964, at *4. Neither EPA nor CDPHE addressed the most important factors: whether the consent decree is in the public interest and upholds the objectives of CERCLA's resource damage provisions, chief among which is the "restoration or replacement of natural resources damaged by unlawful releases of hazardous substances." *New Mexico v. General Elec. Co.,* 467 F.3d 1223, 1245 (10th Cir. 2006)). The CERCLA settlements cannot be entered where EPA has not satisfied CERCLA's requirement for meaningful public comment on proposed settlement agreements (42 U.S.C. § 9622(i)) and CDPHE proposes to amend the 1988 CD/RAP without adhering to its procedural provisions, which includes judicial approval. *Utah by Department of Health v. Kennecott Corp*., 801 F. Supp. 553 at 572 (D. Utah 1992)(setting out substantive and procedural standards of CERCLA settlements and denying approval on the basis that proposed consent decree is "not just and fair or consistent with the purposes of CERCLA.").

None of the relevant factors are addressed by EPA or CDPHE, despite RCA and CERCLA provisions. For each of the proposed agency actions in the package deal, neither agency provided environmental analysis or documentation of the impacts and alternatives to the proposal. Neither agency provided a statement of the basis and purpose for the proposed agency action. Where the intermixed actions of EPA and CDPHE have failed to inform the public and allow comment and hearing on the basis, purpose, and impacts of these actions, the public comment requirements have not been satisfied. Any action taken on the procedures used for the proposals is arbitrary, capricious and not in accordance with law. 5 U.S.C. §§ 701, et seq., C.R.S. §§ 24-5-101, et seq.

III. Colorado's Licensing Actions and Private Agreements are Ultra Vires and Contrary to Law

A. Proposed RCA License Amendment No. 54 Violates State and Federal Law

The proposed Amendment 54 would grant Cotter an UMTRCA license of unlimited term by which Cotter may "possess, store, and dispose of" 11e2 byproduct materials. Proposed License at 10B. The proposed license does not conform to Colorado's license application and review procedures, as set out in the RCA and implementing Part 18 regulations. Substantive comment is futile where CDPHE has not specified whether Cotter has applied for a new license or an amendment/renewal of the license which expired January 2012. Public comment is made futile where Cotter has not filed the application required by Part 18 of Colorado's radiation control regulations. CDPHE has purportedly been regulating according to default regulatory provisions, but has made no effort to prepare the Environmental Impact Analysis required by Part 18.

Colorado's 1982 Agreement State Amendment provided the state with delegated federal statutory authority to license the possession and disposal of byproduct materials. The present proposals ignore the Part 18 regulations that set out the procedural requirements applicable to byproduct licenses. Part 18 licensing requires an application and an analysis by the agency of the impacts and alternatives. 6 CCR 1007-1 § 18.4.1 ("or each license application or application to amend or renew an existing license to […] possess, […] byproduct material as in definition (2) of 1.2.2 which will have a significant impact on the environment, the Department shall prepare a written analysis of the impact of the licensed activity on the environment, which shall be

available to the public and for review by the NRC at the time of public notice of hearing…"). By contrast, the proposed Amendment 54 effectively revokes the Udall Compromise contained in Part 18, which ensures that the agencies prepare a NEPA-like analysis in carrying out their delegated UMTRCA authority. To CCAT's knowledge, CDPHE has never prepared an Environmental Impact Analysis for a Cotter license, renewal, or amendment. CDPHE cannot lawfully consider or approve Amendment 54 without preparing an Environmental Impact Analysis.

Although records reveal that Cotter has requested termination of its license, CDPHE correctly recognizes the Colorado license cannot be terminated until NRC issues a perpetual care license and DOE takes control of the facility. The need for a Part 18 byproduct license with 5-year renewals recognizes that CDPHE does not have indefinite jurisdiction over mill tailings, and CDPHE jurisdiction at the site is limited to the reasonable period necessary to close the facility and transfer the remaining tailings to DOE. By dispensing with the renewal requirement, CDPHE effectively repeals the UMTRCA provisions adopted in response to the ineffective state regulation of uranium mill tailings in Colorado and elsewhere.

CDPHE effectively proposes to provide a "life of operation" license that ignores the 5-year renewal requirements of the Radiation Control Act. Where the proposed license contains an indefinite term of effectiveness, it is clear that CDPHE has unlawfully strayed into the exclusive realm of federal authority over perpetual care of tailings cells. The license, albeit creative, runs contrary to the statutory schemes applicable to uranium tailings.

The significance of the proposed changes to the license and 1988 CD/RAP requires Cotter to file a renewal application, complete with an Environmental Report, followed by CDPHE notice of hearing based on an agency-prepared Environmental Impact Analysis. 6 CCR 1007-1 Part 18. Although CDPHE has repeatedly violated the licensing procedures at other sites, and does not have a current EIA for the Cotter site, prompt compliance with the applicable statutory scheme is necessary to inform the public and the relevant decisionmakers of the impacts and the alternative means to achieve a prompt clean-up. The requirement for an Agreement State to comply with disclosure and analysis requirements of federal law is known as the Udall Compromise, and cannot be discarded by an agreement created between a limited group of PRPs, for the perceived benefit of the PRPs.

B. Uncertainty Does not Preclude Surety for Cotter's Removal Estimate

The License proposes to forego bonding for final disposal costs on the basis that required decommissioning and closure plans have not been prepared. CDPHE reasons that bonding is not required where plans do not exist. EPA simply ignores bonding for full disposal and remediation in its settlement agreement, leaving the question of financial assurance for known contamination to some uncertain date after the RI/FS is complete. SOW at para 82.

Both EPA and CDPHE ignore that Cotter has in fact provided a cursory, initial estimate for groundwater remedy that involves moving the tailings from the current impoundments into a sound, modern disposal facility. Cotter presents an initial estimate that this remedy would cost in excess of $800 million, which would presumably be paid by General Atomics where Cotter has no apparent source of income other than funds provided by the defense contractor's ongoing activities. Although $1billion is a large sum, and may have been inflated by Cotter overstating volumes and transport costs, when this is viewed in context of General Atomics' nuclear programs and the scarcity of water, a $1 billion surety is reasonable and appropriate to the

current knowledge of this and other sites where actual costs far exceeded Colorado and company estimates.

A similar action is under way at Moab, Utah, where, after Atlas' proposed cap-in-place proposal failed and the company went into bankruptcy, the federal government took over the clean-up. 10 C.F.R. § 7912. Popular estimates put the cost to excavate, transport by train, and dispose of the Atlas tailings at Crescent Junction, Utah at approximately $1 billion. The volume at Moab is larger than that at Cotter, but Cotter is also serviced by a train line that may eliminate the need for dual loading and off-site trucking. CDPHE's license renewal, coupled with an oft-repeated cap-in-place preference, leaves the Colorado and federal taxpayer without a surety to cover the foreseeable cost of a Moab-style closure that many in the community believe is required due to the inadequate construction and poor performance of Cotter's leaky impoundments.

Where Cotter has estimated that it could cost in excess of $800 million to isolate its milling wastes from the groundwater by removing them to a competent impoundment, and the groundwater remediation cost for the site and the Lincoln Park neighborhood has not yet been estimated by EPA or CDPHE, a $1 billion financial surety is reasonable under these circumstances. Although the 1988 CD/RAP allows the surety for CERCLA and RCA to be accomplished through a single instrument, the regulatory scheme requires adequate bonding for all reasonably foreseeable closure, reclamation, and remediation activities. The package deal ignores that bonding for the alternative outlined in Cotter's estimate would provide an incentive to avoid the ongoing delay of implementation of CERCLA and UMTRCA requirements since the 1980s.

C. Federal Radon Limits apply During CERCLA Remediation and RCA Closure Activities

CDPHE's statement of basis erroneously claims that "during the closure phase, there is no regulatory limit for the direct radon release from the impoundment and no annual monitoring requirement." Read as a whole, state and federal law requires compliance with the 20 pCi/m2s radon flux standard during all phases of tailings creation and disposal. 6 CCR 1007-1 Part. 18, Criterion 5 ("40 CFR Part 192, Subparts D and E (48 FR 45926; October 7, 1983) […] apply during operations and prior to the end of closure.").

During closure, which has not yet commenced on an approved closure plan with enforceable milestones, the tailings remain subject to the 20 pCi/m2s radon emissions limits in EPA's Part 192 Subpart D regulations. 40 C.F.R. § 192.32(a)(3)(ii)("The Nuclear Regulatory Commission or Agreement State may approve a licensee's request to extend the time for performance of milestones if, after providing an opportunity for public participation, the Nuclear Regulatory Commission or Agreement State finds that compliance with the 20 pCi/m2s flux standard has been demonstrated using a method approved by the NRC, in the manner required in 192.32(a)(4)(i). Only under these circumstances and during the period of the extension must compliance with the 20 pCi/m2s flux standard be demonstrated each year."). Where CDPHE does not even know it has violated EPA's UMTRCA regulations by failing to approve a closure plan that imposes milestones, by failing to demonstrate compliance with the radon flux standards, and by failing to require emplacement of a permanent radon barrier, annual radon monitoring must commence immediately.

Despite these explicit requirements of EPA's Part 192 Subpart D regulations, the proposed license and other documents in the CDPHE/EPA package do not contain milestones for

implementing the closure plan required by state and federal law. 40 C.F.R. § 192.32(a)(3)(i) ("Uranium mill tailings piles or impoundments that are nonoperational and subject to a license by […] an Agreement State shall limit releases of radon-222 by emplacing a permanent radon […] as expeditiously as practicable […] after the pile or impoundment ceases to be operational[…]in accordance with a written tailings closure plan (radon) to be incorporated by the […] Agreement State into individual site licenses." The EPA/CDPHE proposal does not include any requirement to monitor and limit radon emissions and even though the Cotter mill has allegedly entered closure, EPA and CDPHE have ignored their own violations and those of Cotter where the mill has not operated at all since 2006.

Where Colorado has not adopted a closure plan with enforceable milestones, as required by EPA regulations and RCA regulations, the EPA settlement agreement is part of an absurd and illegal situation where CDPHE, perhaps accurately, states its actions are okay because allegedly, "there is no regulatory limit for the direct radon release from the impoundment and no annual monitoring requirement." Where radon flux testing has not taken place for years, and the regulatory scheme requires radon testing where the placement of the cover has been delayed by years, CDPHE amendment of the license to purposely and indefinitely avoid radon testing is contrary to federal law. 40 C.F.R. Part 192 Subpart D *accord* 6 CCR 1007-1 Part. 18, Criterion 5 (confirming EPA regulations "apply during operations and prior to the end of closure.").

Moreover, the impoundments at Cotter are indeed actively receiving additional 11e2 byproduct material and as such, are subject to Clean Air Act Subpart W regulation. EPA has clarified this in previous communications with Cotter, but has failed to take any enforcement action. CCAT reserves the right to seek remedy of what appears to be an ongoing violation of the Clean Air Act and UMTRCA regulations should EPA Region 8 continue its pattern of inaction and deferral to incorrect CDPHE interpretations of the RCA and federal law.

D. The *Agreement Regarding Licensing and Remedial Requirements* ("CD/RAP Amendment") is Invalid and Ultra Vires

First, the so-called "agreement" between Cotter and CDPHE staff purports to amend the 1988 RAP and Consent Decree entered between Cotter and Colorado, without engaging the dispute resolution process and judicial approval required by the Consent Decree. The Consent Decree recognizes the public interest involved by requiring the use of a federal Special Master when resolving disputes between Colorado and Cotter. Retired Judge Richard Dana of the Judicial Arbiters Group has served as Special Master for numerous uranium mill clean-ups, but was inexplicable excluded from the rewrite contained in the Cotter/Colorado Amendment. *See* Section XXIII of the Consent Decree.

Without engaging in an open process, CDPHE staff proposes a CD/RAP Amendment to alter the terms of the RAP and Consent Decree by replacing its terms with those in the EPA settlement, which are the product of a negotiation among a select group of PRPs that have made little progress in addressing issues in the 1988 Consent Decree. The PRP status of Colorado and Cotter helps explain why both have maintained an adversarial relationship with the communities, pushing at every turn to avoid active clean-up of groundwater contamination and ignoring community requests to address the source of contamination – including the leaking tailings impoundments and the disposal of radioactive waste into the deep coal mine shafts at the site.

As such, the proposed CD/RAP amendment, like EPA's proposed CERCLA settlement, is not the result of an open, arms-length negotiation that provided non-parties with the ability to

explain to the court why the modification of the CD/RAP is not in the public interest. Where the court-approved settlement agreement contemplates Special Master oversight of the CDPHE/Cotter disputes, and none took place during the preparation of the CD/RAP Amendment, the federal and state APA prevents its adoption, as does federal common law that recognizes federal consent decrees have *res judicata* effect that cannot be altered without the involvement and approval of the federal court that approved and entered the consent decree in the first instance. *See United States v. Kerr-McGee Corp*., 2008 WL 863975, at *5 (D. Colo. Mar. 26, 2008); *WildEarth Guardians*, 2011 WL 4485964, at *4, *New Mexico v. General Elec*. Co., 467 F.3d 1223, 1245 (10th Cir. 2006)).

E. Proposal Unlawfully Delays Corrective Action Plan for Groundwater Exceedances

Groundwater contamination in exceedance of groundwater standards has been identified and confirmed at the Cotter site for numerous constituents, including uranium, molybdenum, and others. However, neither agency's proposal contains the corrective action program or permits required by EPA radiation regulations at Part 192 Subpart D. 40 C.F.R. § 192.33("If the ground water standards established under provisions of § 192.32(a)(2) are exceeded at any licensed site, a corrective action program as specified in § 264.100 of this chapter shall be put into operation as soon as is practicable, and in no event later than eighteen (18) months after a finding of exceedance."). EPA and CDPHE are simply not authorized to revoke this timeliness provision of this regulation by their private agreement with Cotter.

Like EPA's UMTRCA regulations, CERCLA's more generally applicable regulations are meant to prevent indefinite delay in remediation that characterizes Cotter and the other pre-UMTRCA uranium mills. As the administrative record and consent decree confirms, groundwater exceedances have been occurring for decades. However, the outcome of the agencies' proposal is more delay and more years without remedial action.

IV. Conclusion

The package of agency actions proposed by EPA and CDPHE based on secret negotiations with Cotter Corporation violates state and federal law. Individually, each proposed action would violate state and federal law. As a whole, EPA and CDPHE ignore community concerns in favor of nebulous proposals that continue a thirty-plus history of leaving Cotter in charge of the contamination emanating from its uranium mill and tailings impoundments.

Respectfully Submitted

s/Travis E. Stills

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