

AN ENVIRONMENTAL STUDY OF ACTIVE AND INACTIVE  
URANIUM MINES, MILLS, AND THEIR EFFLUENTS

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ABSTRACT

The purpose of this short-term study has been: 1) to develop broad bases; and 2) to obtain new information relevant to the needs of the Environmental Protection Agency. These data bases are required to provide information for the Clean Air Act and the Uranium Mill Tailings Radiation Control Act. This report, Part I, deals specifically with four tasks associated with the Clean Air Act. They are:

- Task 1. Effect of Bulkheading or Filling Underground Mines on Radon Emission
- Task 2. Radon Daughter Equilibrium at Various Distances from Exhaust Vents of Underground Uranium mines
- Task 3. Incentives for Using Elevated Release Points to Reduce Ground Level Radon Concentrations from Underground Uranium Mines
- Task 4. A Study of the Contribution of Multiple Radon Sources in the Ambrosia Lake District, New Mexico, to Concentrations at Selected Locations

Each task is discussed individually in the following sections of this report.

Two open literature publications are being prepared as a part of this study in addition to the data base. They are:

"Bulkheading Effects on Radon Release from the Twilight Uranium Mine,"  
V. W. Thomas

"Relative Contributions of Radon Sources on Ambient Air Concentrations from Mining and Milling of Uranium," J. G. Droppo and J. A. Glissmeyer

Due to the complexity of the data and the number of tasks, each task has its own summary and recommendation section. However, for ease of reading, the Executive Summary lists all detail with respect to the interpretation of data developed in the tasks and their associated recommendations.

## EXECUTIVE SUMMARY

### TASK 1 - EFFECT OF BULKHEADING OR FILLING UNDERGROUND MINES ON RADON EMISSION

A study of the effects of bulkheading on the radon release from an underground uranium mine was conducted at the Bureau of Mines underground uranium research mine. The research mine is known as the Twilight Mine and is located near Uravan, Colorado. The air flow conditions included exhausting and blowing ventilations with and without bulkheading for six consecutive experimental periods of up to two weeks each. Radon measurements in mine and exhaust air were made for both directions of air flow from bulkhead doors at either end of an internal loop open, closed, and closed but with a major leak. These measurements show that bulkheading produced a major effect on the total radon leaving the mine and that this effect was dependent upon the type of ventilation and the integrity of the bulkheads. During exhausting ventilation, the total radon discharged from the mine decreased by 17% when the bulkhead doors were closed but with a large leak. A further reduction of 35% was observed when the large leak was closed. This latter measurement, however, was made over a very short time period and radon had not built up to its maximum equilibrium concentration. During blowing ventilation, a small (6%) but not significant increase in the total radon leaving the mine was measured when the bulkhead doors were closed but with the large leak. When the large leak was eliminated, a reduction of 35% was observed. Other parameters affecting the total radon leaving the mine, including barometric pressure, must also be taken into consideration when interpreting these measurements. A small amount of air was pumped from the bulkheaded area of the mine to maintain a negative pressure. This air, with its relatively high radon content, could be passed through a sorption trap or discharged at a high elevation to minimize exposure to people in the environs. If this air were passed through absolute sorption traps, it could reduce the radon leaving the mine to 45% and 68%, respectively, of that for exhausting and blowing ventilation with no bulkheading.

#### Recommendations

While valuable information was obtained from this bulkheading experiment, it is recognized that a large-scale experiment should be conducted in

an operating uranium mine. Battelle scientists have met with the Bureau of Mines and with representatives of a major uranium mining company to discuss both the current experiment and a possible experiment in the future at a large uranium mine.

It seems important to compare the potential of bulkheading in a large active mine with the observations which have been made in this very small-scale study. Whereas the experimental mine had somewhat comparable areas of active and inactive regions, an actual working mine may have worked-out regions with tens of times more volume than the working regions. It can thus be surmised that effective bulkheading of active mines could reduce radon emissions by up to an order of magnitude, or perhaps more. If a study were to be conducted at an active uranium mine, one should be selected where the potential for bulkheading of a substantial region of the mine volume is possible. Discussions with mine operators have indicated their willingness to participate in a study if a well-conceived experiment could be devised. From considerations of active mines, it appears that suitable ones are available and that a study which would include the cooperation of the mine operator, the Bureau of Mines, and PNL could be productively carried out.

#### TASK 2 - RADON DAUGHTER EQUILIBRIUM AT VARIOUS DISTANCES FROM EXHAUST VENTS OF UNDERGROUND URANIUM MINES

Data obtained in the study indicate that the ratios of radon daughters to radon are relatively low in exhaust air from the underground uranium mine vents. Since working levels are determined by the total concentrations of radon daughters rather than radon itself, this means that the direct exposure to the ventilation exhaust is much less than it would be if the radon daughters more nearly approached equilibrium with radon. The radon daughter equilibrium measurements made downwind from the ventilation exhaust ports showed low ratios indicating that either radon daughters are scavenged by the aerosols that are contained in the plume or that they are scavenged by contact with the earth's surface. In many cases, the data do not suggest a significant build-up in radon daughters with time during transport of the plume at ground level. The working levels were below the proposed indoor EPA standard of 0.015 at all points exceeding 100 meters from the vent.

### Recommendations

The measurements which have been made in this study indicate that the ratios of radon daughters to radon are relatively low in exhaust air from the vents. Since working levels are determined by the total concentrations of radon daughters rather than radon itself, this means that the direct exposure to the ventilation exhaust is much less than it would be if the radon daughters more nearly approached equilibrium with radon. Measurements downwind from the ventilation exhaust also show low ratios indicating that either radon daughters are scavenged by the aerosols that are contained in the plume, as is apparently the case for the wet exhaust, or that they are scavenged by contact with the earth's surface. In many cases, the data do not suggest a significant build-up in radon daughters with time during transport of the plume. Difficulties in making the measurements, however, preclude a firm statement as to the long-range radon daughter build-up during transport of the plume. It may well be that over distances of a few kilometers and time periods of an hour or more, that the radon daughters do approach equilibrium with their radon parent which has come from the mine exhaust vents.

To determine if this is actually true would require some additional measurements. We recommend that as time and funding permit, a significant research program be initiated to determine the ratio of radon to its daughters at considerable distances from mine exhausts or stockpiles and tailings piles in the uranium mining and milling areas. This information is needed to determine in an absolute way what the local and regional effect of radon release from mine ventilation air and from other sources is.

### TASK 3 - INCENTIVES FOR USING ELEVATED RELEASE POINTS TO REDUCE GROUND LEVEL RADON CONCENTRATIONS FROM UNDERGROUND URANIUM MINES

The conclusions drawn are based on a reasonably small data base. Although some general guidance relative to the effects of elevated releases is offered, more definitive information could be generated on a site-specific basis, particularly in the case of strongly biased distributions of wind direction and/or population. Conclusions drawn with the aid of the Hanford and Black Fox data bases are:

- Despite differences in meteorology, different sites can have very similar annual average distributions of concentration.

- Despite similarity of magnitude and distribution of ground-level concentration resulting from ground-level releases, the two sites displayed quite different ground-level concentrations following modeled elevated releases. A greater reduction in concentration was associated with the site with more stable atmosphere (Black Fox).
- A 20-m release elevation reduces annual average concentration (when compared to a ground-level release) by about 60% at one mile from a source, and by about 30% at ten miles from the source.
- The axis of maximum benefit from elevated releases cannot be specified on the basis of the concentration distribution generated by a ground-level release.
- The height of the mixing layer has a relatively small influence on the benefit accruing as the result of elevated releases. Specifically, the elevated release benefit is about the same for a modeled 200-m inversion "lid" or a 1000-m inversion "lid."
- Benefits, in terms of reduced dosage to population per unit of stack height increase, decrease as stack height increases. This conclusion is documented in Figure 9.

Beyond roughly 1.5 miles from the centroid of up to three 20-m stacks' (spaced a mile or less apart), the effect of stack locations is minimal.

#### Recommendations

The scope and funding of this task did not permit an examination of concentrations resulting from a large number of the possible combinations of site meteorology, source configurations, source heights, and atmospheric mixing heights. If one were to evaluate this technique in principle for all underground uranium mining sites, a large variety of site and meteorology parameters would need to be considered. By studying a major number of underground mines in this manner, one would be able to intercept the impact of using elevated releases to reduce ground-level radon concentrations from the entire underground uranium mining industry. The data generated from this study indicate that the effects of elevated releases are very site-specific. This type of study is particularly applicable to assess the radon dose received by receptors in the vicinity of a mine.

TASK 4 - A STUDY OF THE CONTRIBUTION OF MULTIPLE RADON SOURCES IN THE  
AMBROSIA LAKE DISTRICT, NEW MEXICO, TO CONCENTRATIONS AT  
SELECTED LOCATIONS

Uranium mining and milling operations result in a multitude of radon releases of varying source strength. An analysis is performed of the relative importance of these various radon releases on ambient atmospheric radon values. A uranium mining and milling region is selected to provide case study data on the locations, numbers, and magnitudes of releases. A comprehensive list of radon releases is compiled. Then using the best available information, source terms are generated for each location. Estimates of the atmospheric transport and dispersion of these emissions provide a framework for comparison of the relative contributions of atmospheric radon. The mine vent radon releases contribute a much larger fraction of the incremental atmospheric radon values than tailings piles. Although a few mine vents do have large radon emission rates, the large number of smaller mine releases constitutes a major fraction of total radon emissions.

Recommendations

The source term data have clearly pointed out the importance of the vent releases in total radon incremental concentrations. Future studies should have stronger emphasis on the vent releases. The models should account for actual configuration of vent releases (size, elevation, exit velocity, etc.). The assumption of ground-level releases may be resulting in considerable overestimation of short-range concentrations.

Verification of the modeled concentrations should be made using monitoring data and onsite studies of specific dispersion conditions.

The results should be generalized to other regions by comparisons of the vent configuration, numbers, and locations. Should the annual radon concentrations be limiting, similar efforts should be undertaken for other regions.

## TASK 1

### EFFECT OF BULKHEADING OR FILLING UNDERGROUND MINES ON RADON EMISSION\*

#### INTRODUCTION

Bulkheading in underground mines is a common practice, and it is performed with the objective of controlling ventilation air to maximize air quality to which miners are exposed, while minimizing the total amount of air movement required. In a very practical sense, bulkheading is essential for many underground mining operations to permit the proper ventilation of working areas. In some cases, bulkheading may effectively exclude major sections of underground uranium mines from the ventilation pattern. There are, however, problems involved in bulkheading, the major one being that there can be leakage from the bulkheaded area back into the working area. The radon concentrations behind bulkheads may be orders of magnitude higher than those in work areas, and such a leakage could have serious consequences on exposure to mine workers. For this reason, it is common practice to maintain a bulkheaded area at a slightly negative pressure. The exhaust ventilation rate required to maintain the slight negative pressure behind the bulkheads is small compared to the additional ventilation which would be required without the bulkheading. This assures that any leakage through the bulkheads will be from the working areas to the bulkheaded areas and should, therefore, prevent unexpected high exposures in working areas. When the bulkheaded area is kept at a slightly negative pressure (nominally 0.03 cm water) with respect to the active areas, the air being pumped from behind the bulkhead which contains very high radon concentrations can be released to the environment outside the mine or passed through a radon sorption trap prior to release.

While the bulkheading operation provides an important function in permitting practical ventilation of underground working areas, it also probably

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\*This work was carried out jointly with the U. S. Bureau of Mines. An open literature publication entitled "Bulkheading Effects on Radon Release from the Twilight Uranium Mine" has been prepared by V. W. Thomas, PNL, Richland, WA, and C. S. Musulin and J. C. Franklin, U. S. Bureau of Mines, Spokane Research Center.

has a significant effect on the total radon released to the atmosphere. The objective of this current study is to determine what the magnitude of this effect is during both exhausting and blowing ventilation.

#### EXPERIMENTAL PROTOCOL

The Twilight Mine (Figure 1) just north of Uravan, Colorado, was selected as the site for the investigation. This mine is leased from Union Carbide by the Bureau of Mines and is operated as a research mine for the Bureau of Mines by the Adare Contracting Company. The Twilight Mine is small, with two entry portals connected to each other by a single loop drift of about 360 m in length (Figure 1). Two internal loops have been mined off from this main loop. The larger of these, which is about 250 m in length, is equipped with bulkheads at either end. Each end can be opened or closed by doors. The bulkhead at 1L9 is penetrated by two small diameter pipes (5 cm and 8 cm) which are normally used to pump water and/or diesel fumes into the bulkheaded portion of the mine for experimentation purposes. In this study one of these pipes was used to provide a negative pressure of about 0.03 cm of water behind the closed bulkheads with respect to the rest of the mine. A larger (60 cm) pipe penetrates both bulkheads and can be opened or closed by means of louvered shutters.

The main ventilation fans are located at Portal B. They may be reversed to provide either exhausting ventilation or blowing ventilation. In the experiment, exhausting ventilation rates averaged 390 m<sup>3</sup>/min and blowing ventilation averaged 550 m<sup>3</sup>/min. The experiment was conducted in four major phases using two modes of ventilation:

- Phase I: Exhausting ventilation with bulkhead doors open
- Phase IIA: Exhausting ventilation with bulkhead doors closed, 60 cm pipe shutters open (leaky bulkhead)
- Phase IIB: Exhausting ventilation with bulkhead doors closed, 60 cm pipe shutters closed
- Phase IIIA: Blowing ventilation with bulkhead doors closed, 60 cm pipe shutters open (leaky bulkhead)
- Phase IIIB: Blowing ventilation with bulkhead doors closed, 60 cm pipe shutters closed

