There Are Safe Limits for Radioactivity – Does WIPP Need to Filter its Exhaust Air?-17165

Punam Thakur, Brant Lemons, Hnin Khaing, Russell Hardy

Carlsbad Environmental Monitoring & Research Center, 1400 University Drive, Carlsbad, NM 88220, USA

ABSTRACT

On February 14, 2014, an incident in Panel 7, Room 7 of the Waste Isolation Pilot Plant (WIPP) underground repository resulted in the release of americium and plutonium (mostly ^{241}Am) into the environment and contaminated portions of the repository, primarily along the ventilation path from the location of the incident. The WIPP uses a ventilation system to ensure that underground air is circulated through the repository and to ensure that air quality conditions are safe for the workers. Since the air in the repository exits to the surface through an exhaust shaft, this shaft is the sole potential pathway for airborne radioactivity release from the repository. During normal operations before the 2014 incident, exhaust air was released to the environment unfiltered, with an automatic switch to filtration when airborne radioactivity was detected immediately down-stream from the active waste disposal operation. However, since the radiation release event, the WIPP ventilation system has been, and will likely remain in what is called “filtration mode,” (i.e., exhaust air is routed through a HEPA filter system). Redirection of the ventilation system through the HEPA (High Efficiency Particulate Air) filter system was necessary at the peak of the radiation release event to protect aboveground workers at the site and the public in the surrounding areas; however, it has hampered recovery efforts and has exacerbated the inherent safety issues of working underground.

As a component of the Carlsbad Environmental Monitoring & Research Center’s (CEMRC) WIPP environmental monitoring program, airborne radioactivity samples are collected daily in the exhaust shaft ventilation air as it reaches the surface, and before entering the HEPA filters. Since June 2014, airborne radiation levels entering the HEPA filters have averaged about 1% of a derived air concentration (DAC) for ^{241}Am. An airborne radioactivity level of one DAC is equivalent to a potential worker internal dose exposure of 50 mSv per work year, if a worker were continuously exposed for a full work year (2000 hours). During Project Reach and throughout decontamination campaigns conducted in Panel 7 for several months in 2015, these unfiltered levels rose to 3-5% of a DAC, with a one week spike reaching almost one DAC in June 2015, during decontamination of the most heavily contaminated exhaust drift in Panel 7. Since that period, the unfiltered levels have never exceeded 2% of a DAC. Going forward, the question is, should WIPP resume unfiltered discharge of its underground ventilation air? Evaluation of more than two years of underground ventilation sampling data indicates that residual radioactivity levels in the underground no longer warrant HEPA filtration in order to meet either worker or environmental protection criteria. In terms of radiological risk at or in the vicinity of the WIPP site, the increased risk from

resuming unfiltered ventilation is exceedingly small and would not result in a hypothetical dose to a member of the public in excess of the 100 micro Sv per year limit for periodic confirmatory sampling as required for operating repositories by the Environmental Protection Agency (40 CFR 191). In addition, the requirement for respiratory protection for workers underground exposed to 1-2% of a DAC is questionable, given the added industrial safety risk of heavy equipment operation while wearing respirators.

INTRODUCTION

The Waste Isolation Pilot Plant (WIPP) is the nation's only deep geologic repository for the permanent disposal of transuranic (TRU) waste generated primarily from the research and production of nuclear weapons. Located in the Chihuahuan desert of southeastern New Mexico near Carlsbad, the WIPP repository is mined in the Salado Formation, a bedded salt formation of the Permian era, approximately 655 m (2150 ft.) below land surface. The repository, which opened in March 1999, has since disposed of more than 90,000 m^3 of TRU waste in more than 165,000 containers, cleaning up 22 generator sites nationwide. Over its lifetime, WIPP is expected to dispose of approximately 175,000 cubic meters of TRU waste from various DOE (Department of Energy) sites. Currently, the WIPP is about half-full in terms of its legally-defined capacity.

The underground repository is ventilated by drawing in outside air from the surface through intake shafts via fans at the top of an adjacent dedicated exhaust shaft. Before the 2014 incident, a total of five exhaust ventilation fans could pull air through the underground as shown in Figure 1. These fans are located on the surface of the WIPP facility near the Exhaust Shaft. Two of these are the unfiltered main fans, and three are smaller fans that can be used with or without filtration. These fans were operated in various configurations to provide the necessary airflow to the underground. Since the air in the repository exits to the surface through its exhaust shaft, this shaft is the sole potential pathway for airborne radioactivity release from the WIPP. During normal operations, exhaust air was released unfiltered. In the event of a radiological accident involving waste underground, the exhaust air would be filtered through a standby HEPA (High Efficiency Particulate Air) filtration system just prior to being released to the atmosphere. This automated actuation of "filtration mode" was intended to protect above-ground workers at the site and the public in the surrounding areas by minimizing radiation releases to the environment as a result of a radioactive release occurrence underground. Continuous air monitors (CAMs) located underground controlled whether or not the ventilation returning to the surface was passed through these large filter systems before release to the atmosphere.

The WIPP repository was sited successfully and had been operating safely and efficiently for nearly 15 years prior to an accidental airborne radiation release from the repository on February 14, 2014 (*www.wipp.energy.gov*).The radiation release was caused by a runaway chemical reaction inside a transuranic (TRU) waste drum, which overheated and ruptured underground, spilling radioactive materials into the repository [1]. It was the first release at the WIPP since its opening. The accident released moderate levels of radioactivity, mostly americium and plutonium, into the repository and was detected by an underground CAM located near panel 7, where waste had most recently been emplaced. A small, but measurable amount of radioactivity also escaped to the surface and was detected beyond the site's inner boundary. Fortunately there were no personnel in the underground at the time of the release, as waste emplacement operations had been suspended nine days earlier on February 5, 2014 because of an unrelated fire incident. As soon as the CAM alarmed on the night of February 14, as designed, the underground ventilation system automatically switched to HEPA filtration and a surface-mounted by-pass damper was manually closed, thereby achieving the designated airflow criteria. As a process of switching to the filtration mode, the airflow through the repository was reduced from 12,000 m^3 per minute to 1,700 m^3 per minute and has been operating in the filtration mode since that time.

In response to this event, the CEMRC, as well as the WIPP's own compliance-monitoring program, conducted extensive monitoring in and around the WIPP site. Both monitoring efforts concluded that environmental contamination levels were very low and localized and posed no harm to the public or the environment. The highest airborne activity detected was 115.2 µBq/m^3 for ^{241}Am and 10.2 µBq/m^3 for $^{239+240}$ Pu at a sampling station located 0.1 km away from the underground air exhaust point, and 81.4 µBq/m^3 of ^{241}Am and 5.8 µBq/m^3 of $^{239+240}$Pu at a monitoring station located approximately 1 km northwest of the WIPP facility, in the direction of the wind prevailing at the time of the release. These low airborne concentrations suggest that any increased risk to either surface workers or the nearby public was exceedingly small. Bioassays conducted in the days following the incident showed that 22 workers received low internal doses with no long-term adverse health effects expected for these employees. Based on bioassay results and model prediction, the DOE estimated that the highest maximum inhalation dose that this cohort of exposed workers received was about 0.08 mSv, which is less than the level required for reporting dose exposures.

After months of investigations into the cause of the radiological release, the DOE released a recovery plan at the end of September, 2014 [2] that outlined the steps necessary to clean up and to resume limited waste emplacement operations by the end of the 2016. Unfortunately, reduced airflow in the WIPP underground poses a significant challenge to the recovery efforts and has exacerbated the inherent safety issues of working underground. This article presents an evaluation of more than two years of underground ventilation sampling data indicating that residual radioactivity levels in the underground no longer warrant a policy of 100% filtration in order to meet either worker or environmental protection criteria. Instead, a potential way to improve ventilation of the WIPP underground may be to simply resume the pre-event ventilation system operation. That is, nominally unfiltered discharge of underground exhaust directly to the atmosphere, along with underground airborne radioactivity monitoring that automatically switches to filtration mode if elevated levels are detected. This ventilation mode successfully prevented a significant release in the February 2014 incident, and would do so in some future accident.

RADIOLOGICAL RELEASE PATHWAYS AND MESUREMENTS

Underground air flows up the exhaust shaft, passing an effluent monitoring station, Station A, as shown in Figure 1. Unfiltered exhaust air from the underground is sampled at Station A, which has an array of representative fixed air samplers (FAS) in the airstream. Representative samples are collected using shrouded-probes around the FAS intake manifolds. A second effluent monitoring station located downstream of the HEPA filtration system, Station B, samples the underground exhaust air after HEPA filtration, when the repository is operating in “filtration mode”, as it has been since the 2014 event. A separate fan system (from a set of three) pulls the air through a pair of HEPA filtration banks. Station B, like Station A, has shrouded probe FAS systems installed for representative sampling, enabling quantitative assay of radioactive materials released through each location. The analysis of these filters is designed to show how well the HEPA filters work to trap the underground airborne radioactivity. The filter sample collected the morning after the event at Station A (before exhaust air enters the HEPA filter) showed high levels of radioactivity, as expected, about 4337 Bq/m^3 of ^{241}Am and 671 Bq/m^3 of $^{239+240}$Pu. The sample collected the very next day showed about 342 Bq/m^3 of ^{241}Am and 38.8 Bq/m^3 of $^{239+240}$Pu. By the morning of February 21, these levels had dropped to 0.2 Bq/m^3 of combined Pu and Am. Station B (air after HEPA filtration) showed much lower levels, about 2.3 Bq/m^3 of ^{241}Am and 0.22 Bq/m^3 of $^{239+240}$Pu when it was collected on February 18. Three days later it was about 0.43 Bq/m^3 of combined Pu and Am. The time series of ^{241}Am and $^{239+240}$Pu concentrations in the filter samples collected from Station A and Station B are shown in Figure 2.

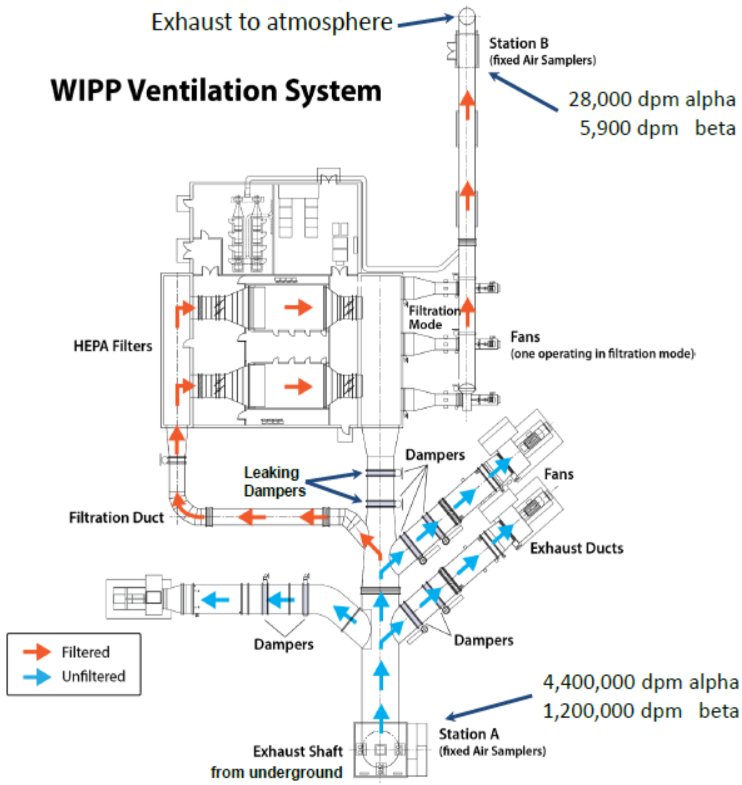
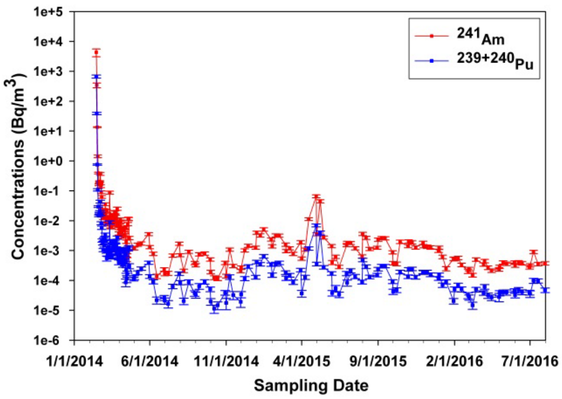


Figure 1. WIPP ventilation system

UNDERGROUND SOURCE TERM ESTIMATION

To assess the magnitude of the accident and potential radiological doses received by the general population, it was important to estimate the source term of the radiological release into the environment. According to source-term estimation, approximately 11 to 55 GBq (0.3 to 1.5 Ci) of radioactivity was released [3] from the breached drum into the WIPP underground and an undetermined fraction of that source term became airborne, setting off a CAM alarm and triggering the closure of dampers designed to force exhausting air through the surface-mounted HEPA filter banks. This source term estimation is based on the post event analysis of underground CAM filters located at the end of the panel 7 exhaust drift, the surface swipes and smear samples collected from the event area, the debris ejected from the breached drum, and results from a 1998 experimental study of the transport and fate of particulate releases from an underground WIPP waste room. This suggests that between 5% and, at most, 20% of the radiological inventory from the estimated ~300 GBq (9 Ci) [4] contained within the suspect waste drum (drum # 68660) was released as suspended airborne radioactive material from Panel 7 and Room7.



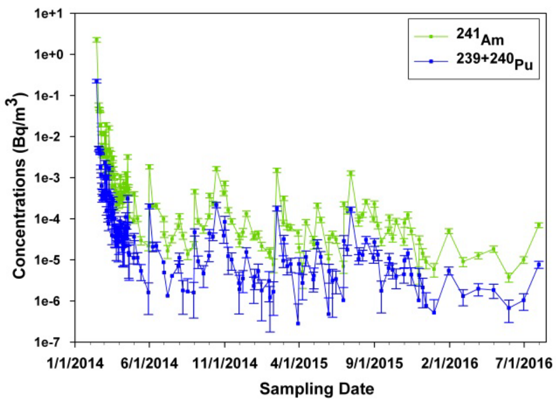


Figure 2. ^{241}Am and $^{239+240}$Pu concentrations in Station A (Pre-HEPA) and Station B (Post HEPA) filters following the February 14, radiation release event at the WIPP.

Of this airborne release underground, the total reaching the top of the exhaust shaft can be estimated by calculating the total flow and integrating measured Station A concentration. The Station A source term is thus estimated to be about 4 GBq (100 mCi) of total activity based on the analyses of filter samples collected by both CEMRC and the WIPP's contractor during the event. The amount of airborne radioactivity based on Station B samples defines the source term of contamination that ultimately escaped from the repository and was calculated to be around 50 MBq (1.3 mCi). An isotopic analysis performed by CEMRC on the Station A and Station B filters in operation during the course of the release showed that approximately 90% of the activity was ^{241}Am, with $^{239+240}$Pu and ^{241}Pu each contributing about 5 % of the total, which closely matched the overall isotopic makeup of the measured contents of the burst drum 68660. The physical properties (e.g., particle size distribution, chemical form of ^{241}Am) of the airborne materials released during the event is not known; however, it is likely similar to combustion particulate since the chemical reaction was strongly exothermic, thereby making the majority respirable, ranging from submicron up to 10-μm AMAD (activity median aerodynamic diameter).

EFFECTS OF THE RADIOLOGICAL RELEASE

The radiological release incident has changed WIPP from a "clean" nuclear facility to one that simultaneously operates in contaminated and uncontaminated areas for the foreseeable future. As a result of the radiological event, portions of the WIPP underground - primarily those portions along the ventilation path from the location of the incident to the top of the exhaust shaft are contaminated. As a result, decontamination of work areas is a key element of the WIPP Recovery Plan. Radiological surveys were performed to determine the extent of the contamination in the WIPP underground with radiological survey results of Panel 7 showing general surface alpha contamination is “fixed” contamination. Some radiological decontamination activities were performed by wetting down the salt walls and floors to form a thin layer of brine on the surface that, once dry, secures the alpha particles to reduce surface contamination/re-suspension levels. In addition to the water spray, in some areas of the underground, WIPP personnel have covered the floor of the mine with brattice cloth (polyethylene textile) and placed a layer of previously mined uncontaminated salt on top of the cloth to further trap any contamination on the floor and to provide a durable surface for vehicle traffic. This, according to the DOE, removes about 95% of the surface contamination.

The nature of the host disposal rock itself (Halite/Salt) also greatly contributes to the decontamination effort. Salt is hygroscopic, that is, when the relative humidity of the ventilation air brought from the surface reaches about 72%, water condenses out of the vapor phase and forms a think brine layer on all exposed surfaces. The radioactive particulate on the halite surfaces is “lifted” into this newly formed brine layer. When the humidity goes back down, the brine evaporates, and the particulate is trapped in the recrystallized surface of the rock. Repeated high humidity clycles over many months drive the radioactive particulate even deeper. Significant mechanical abrasion is needed to resuspend the particulate to create elevated airbore radioactivity levels. This is why the measured Station A levels dropped so dramatically, and stayed low, even with substantial worker and equipment disturbance.

It is important to note that a vast majority of the underground is not affected by the radiological event. Additionally, radiological decontamination activities will not be performed in technically challenging areas like the exhaust shaft (655 vertical meters). When waste emplacement operations resume in the WIPP underground, currently estimated to occur in early 2017, there will be both clean and contaminated areas within the WIPP disposal area.

WIPP VENTILATION ISSUES

The current limited ventilation rates at the WIPP underground (airflow rate reduced to ~1700 m^3 per minute in filtration mode from 12,000 m^3 per minute before the accident) pose a significant challenge in the recovery and resumption of waste disposal operations at WIPP. Operations impacted by this reduced air flow include activities that produce exhaust or fumes (e.g., diesel engines for roof bolters, fork lifts, salt haul trucks, underground construction vehicles) and create underground dust (e.g., mining, roof bolting, vehicle movements, movement of salt). With current reduced ventilation rates, at most only two pieces of underground diesel equipment can be operated simultaneously while maintaining adequate airflow conditions for personnel and the active waste emplacement panel. This means that many underground recovery activities, especially those involving diesel equipment, must be conducted in series, rather than concurrently, until additional ventilation capacity is obtained. A recently installed new “interim” ventilation system is up and running and is expected to nearly double the amount of air in the underground to ~3100 m^3 per minute. Similarly, the addition of a supplemental ventilation system will enable the WIPP underground to be reconfigured in a manner that will allow the underground to function as two separate ventilation systems comprising one that is clean and one that is contaminated. The reconfiguration will be achieved through the use of bulkheads, overcasts and airlocks. Additional airflow will be obtained by the installation of a fan in the underground near the air intake shaft to draw additional air down the air intake shaft and exhaust this clean air out the salt shaft. The combined interim and supplemental ventilation systems will provide 5,100 m^3 per minute of airflow underground, a sufficient ventilation flow needed to support limited waste emplacement operations. A new permanent ventilation system is currently being designed to enable WIPP underground operations to return to full operation, unrestricted by ventilation rates. However, this new permanent ventilation system is estimated to cost several hundred million dollars and will not be ready until 2021.

An alternative way to improve ventilation of the WIPP underground immediately may be to simply reverse the policy of 100% filtration of underground air. One might question the impact of resuming unfiltered ventilation such as whether a sudden flow increase could stir up unfixed contamination and result in a “puff”, creating a potential dose to the workers underground and perhaps to the local public in general by allowing air to exit the repository unfiltered. To investigate whether fluctuations in ventilation, or higher flows might resuspend radioactive particulate airborne radioactivity samples were collected daily in the exhaust shaft ventilation air as it reaches the surface, before entering the HEPA filters. Since June 2014, the unfiltered levels have averaged about 1% of a DAC for ^{241}Am. During Project Reach and subsequent decontamination campaigns conducted in Panel 7 for several months in 2015, these unfiltered levels rose only to 3-5% of a DAC for ^{241}Am, with a one week spike during decontamination of the most heavily contaminated exhaust drift in Panel 7 reaching almost one DAC for ^{241}Am in June 2015. Since that period, the unfiltered levels have never exceeded 2% of a DAC for ^{241}Am. Further, as the recently installed interim ventilation system was connected into the exhaust circuit following the removal of the final upstream flange, daily measurements were made on the pre-filtration exhaust air to investigate whether underground ventilation rate changes affected airborne radioactivity levels. The results showed no correlation between the flow rate and the airborne radioactivity level, which continue to remain less than about 1% of DAC for ^{241}Am. While levels do fluctuate day-to-day, resuspension does not appear to be affected by changes in the ventilation rate.

CONCLUSION

The recovery and resumption of TRU waste disposal operations at WIPP are crucial to the DOE’s national Cold War legacy clean-up mission. Since the radiological event, the underground ventilation system has been operated in filtration mode and will continue to be operated in this configuration for the foreseeable future. The current limited ventilation rate poses a significant challenge in the recovery and resumption of waste disposal operations at WIPP. Increasing ventilation capacity is a principal requirement in the reopening and resumption of waste disposal operations at WIPP. The installation of additional/new ventilation systems in several stages is planned to enable WIPP underground operations to return to full operation capacity such as those that existed prior to the underground radiation event. However, achieving the total airflow necessary for restoring the facility back to full unrestricted ventilation levels has been a lengthy and costly process. While redirection of the existing ventilation system through the HEPA filters was necessary at the peak of the radiation release event to protect aboveground workers at the site and the public in the surrounding areas, the analyses of more than two years of underground ventilation sampling data indicates that residual radioactivity levels in the underground no longer warrant HEPA filtration in order to meet either worker or environmental protection criteria. Therefore, it is our opinion that DOE should consider resumption of the unfiltered discharge of underground ventilation, and resumption of underground monitoring to automatically switch to filtration is elevated levels are detected. Recent ventilation sampling data indicate that there have been no detectable releases that would have resulted in a hypothetical dose to a worker or a member of the public in excess of the 0.1mSv (10 mrem) per year limit for periodic confirmatory sampling as required for operating repositories by the Environmental Protection Agency (40 CFR 191).

ACKNOWLEDGEMENT

This independent research is funded by U.S. Department of Energy (US-DOE) through grant from the Carlsbad Field Office (CBFO) to the New Mexico State University at Carlsbad. We gratefully acknowledge **Roger Nelson** (Former DOE, Chief Scientist) for his thoughtful comments and suggestions which helped us to improve this manuscript.

REFERENCES

[1] DOE, 2015a. U.S. Department of Energy Accident Investigation Report, Phase - II.
Radiological Release Event at the Waste Isolation Pilot Plant on February 14, 2014,
Washington, DC: U.S. Department of Energy. Accessible at:http://www.wipp.energy.gov/Special/AIB_WIPP%20Rad_Event%20Report_Phase%20II.pdf

[2] DOE, 2015b. U.S. Department of Energy, WIPP Waste Isolation Pilot Plant Recovery web site, accessed 09-29-2015, http://www.wipp.energy.gov/Special/Station%20B.pdf

[3] C.H. Hunter and B.J. Viner. Radiological Source term estimates for the February 14, 2014
WIPP release event. SRNL-STI-2014-00579.

[4] J.M. Giaquinto, RE: WIPP-HEPA MOD –filter dose rate can be used to estimate release
source term, e-mail communication to C.H Hunter , December 11, 2014.