
Radioactive Contamination of Packing Materials from a Xenon-133 Shipment

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Objective: We report on radioactive contamination of packing materials from a ^{133}Xe shipment.

Methods: A 2-vial ^{133}Xe shipment was monitored using a survey meter before opening. Both vials were immediately assayed in a dose calibrator. The packing materials were monitored and contamination was detected.

Results: The maximum surface reading of the shipment was $7.0 \mu\text{Sv/h}$. This was higher than previous shipments ($1.1 \pm 0.3 \mu\text{Sv/h}$). One vial was 544 MBq while the other vial was only 474 MBq. Previous shipments were $565 \pm 13 \text{ MBq/vial}$. Monitoring and imaging revealed ^{133}Xe contamination within the packing materials. Xenon-133 escaped from the packing materials over time. The lower activity vial continued to leak ^{133}Xe over time.

Conclusion: Careful monitoring of ^{133}Xe shipments before and after opening along with assaying vials on receipt can indicate vial leakage and radioactive contamination so steps can be taken to minimize radiation exposure to the staff.

Key Words: xenon-133; radioactive contamination; radiation monitoring

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On a Monday morning, we received our weekly standing order shipment of ^{133}Xe gas for use in lung ventilation studies. The package contained two 370-MBq (10-mCi) ^{133}Xe vials precalibrated for the following Thursday at 12:00 pm CT. Exposure rates were measured at the package surface and at 1 m using a Geiger-Müller survey meter. The package was opened and the ^{133}Xe vials were individually assayed in a dose calibrator. The package was surveyed for radioactive contamination using a survey meter before disposal. Contamination of the polystyrene packing materials was detected. We present an evaluation of this contamination.

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MATERIALS AND METHODS

After detecting contamination of the packing materials, the entire package was placed immediately in a fume hood. Individual surveys of the packing materials and the package were repeated to isolate the contamination. Each set of the contaminated polystyrene packing materials (Fig. 1) that held each shielded ^{133}Xe vial were sealed in separate plastic bags. Five-minute computer images were acquired of each set of packing materials using a scintillation camera equipped with a low-energy all-purpose collimator and 20% energy window centered around 81 keV.

Additional images over time were obtained of the 1 set of polystyrene packing materials that had the majority of the contamination. It was removed from the plastic bag while in a fume hood, and separated into its 2 halves. Each half was immediately placed into separate resealable plastic bags and imaged. Both halves were stored in a fume hood with one half remaining in its bag at all times, while the other half was removed from its bag, except when imaged. Images of both halves were obtained over time. Background images were obtained for all imaging sets. A used ^{133}Xe vial was assayed and imaged to estimate the activity of the contamination.

The package and all of its packing materials were stored in a fume hood except during imaging. At the end of work day, all the polystyrene packing material was removed from the plastic bags and stored in a fume hood overnight. The next morning, the package and its packing materials were surveyed using a survey meter. The 1 set of polystyrene packing materials with the majority of the contamination was imaged for 10 min on the scintillation camera. Both ^{133}Xe vials from this shipment were assayed in a dose calibrator over several days.

RESULTS

The initial survey of the surface of the package had a maximum exposure reading of $7.0 \mu\text{Sv/h}$ (0.7 mR/h). This was higher than previous Monday standing orders, $1.1 \pm 0.3 \mu\text{Sv/h}$ ($0.11 \pm 0.03 \text{ mR/h}$, $n = 10$). After opening the package, the dose calibrator assays of the ^{133}Xe vials revealed that 1 vial was 544 MBq (14.7 mCi) while the other vial was only 474 MBq (12.8 mCi). The first vial was slightly lower in activity compared to typical Monday morning (~ 07:30 ET) assays,



FIGURE 1. Packing materials for a shipment of 2 ^{133}Xe vials. Each vial is packed in separate polystyrene packing materials that consist of 2 halves with 5 holes that can house up to 5 shielded ^{133}Xe vials. A single vial is placed in the center hole. Each set of packing materials is placed in a cardboard sleeve to hold the 2 halves together.

$565 \pm 13 \text{ MBq}$ ($15.3 \pm 0.3 \text{ mCi}$, $n = 18$) while the other vial was approximately 90 MBq (2.5 mCi) less than expected.

After assaying the second vial, immediate monitoring of the empty package demonstrated contamination of the packing materials with the primary contamination in 1 set of the polystyrene packing materials. Figure 2 demonstrates the contamination was distributed throughout the polystyrene packing materials. The highest concentration was found around the center hole where the shielded ^{133}Xe vial was held during shipping. These images show that over time there was some

escape of the ^{133}Xe from the polystyrene materials while being enclosed in the plastic bag. Figure 3 demonstrates that ^{133}Xe contamination readily escaped from the polystyrene packing materials that were left unsealed in the fume hood over time.

Based on the assayed and imaged used ^{133}Xe vial, the ^{133}Xe activity of the contaminated polystyrene packing materials was estimated to be approximately 1628 kBq ($44 \mu\text{Ci}$). This initial image was about 40 min after the package was first opened; therefore, the activity in the packing material most likely would have been higher at the time when it was first opened.

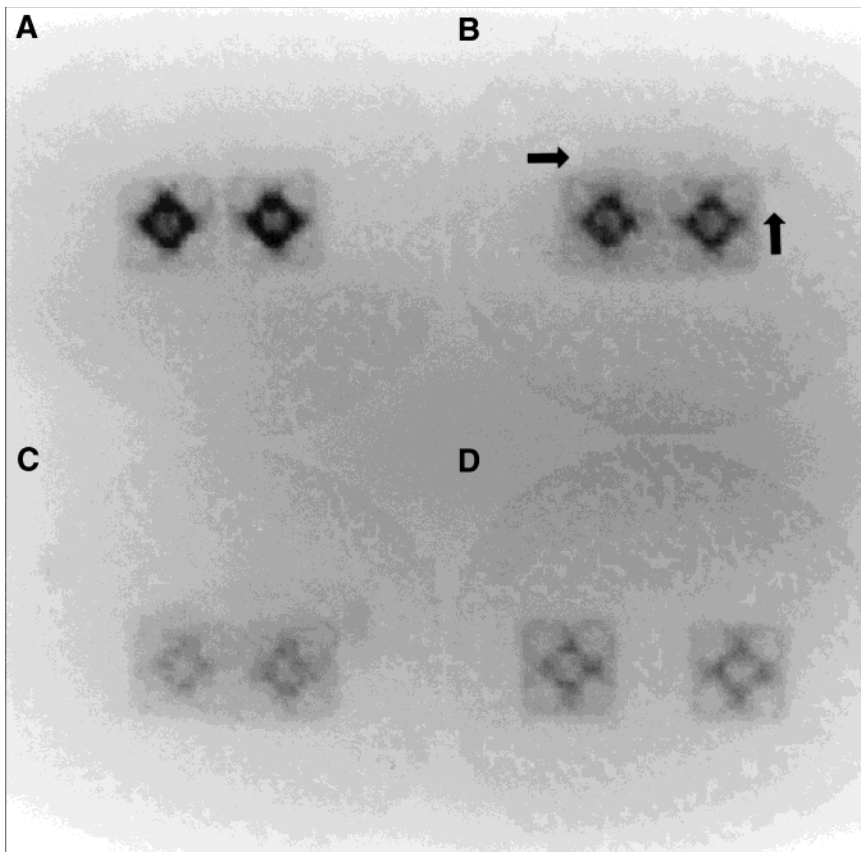


FIGURE 2. Images of polystyrene packing materials that contained the majority of the contamination. The holes of each half used to hold shielded ^{133}Xe vials are facing the camera. (A) Initial image. The 5 holes of each half of the packing materials can be seen with the majority of the counts surrounding the center hole that housed the apparent leaking ^{133}Xe vial. Images B-D are normalized to A. (B) Delay of 0.9 h. Decrease in counts in the center hole with increased counts throughout other parts of the packing materials and into the airspace of the bag (faint activity noted by arrows). (C) Delay of 2.7 h. The overall counts have decreased probably due to leakage of ^{133}Xe from the bag. (D) Immediately after image C was taken, the 2 halves of the polystyrene shipping container were separated and placed in separate resealable bags. D is clearer than C due to the elimination of ^{133}Xe gas from the airspace surrounding the packing material.

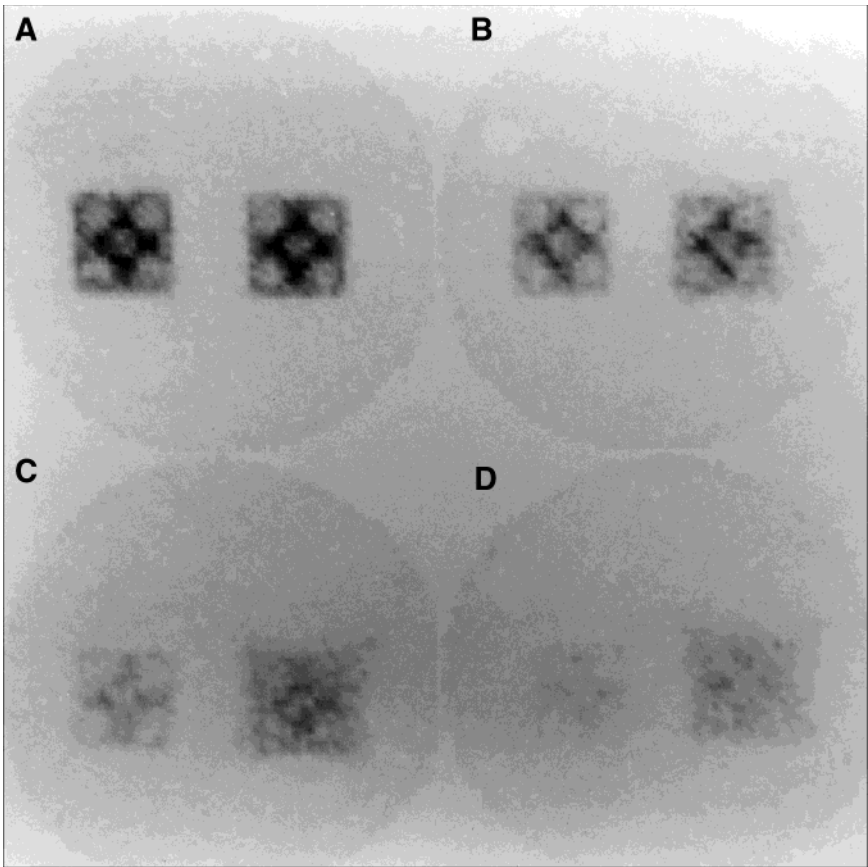


FIGURE 3. Images of the separated polystyrene packing materials that contained the majority of the contamination. The half on the left of each image was stored out of its bag in a fume hood while the one on the right was stored in its bag. (A) Initial image (same as Figure 2D). Images B-D are normalized to A. (B) Delay of 0.7 h from image 3A. (C) Delay of 2.1 h from image 3A. (D) Delay of 4.2 h from image 3A. Xenon-133 readily left the half that was not stored in a bag although activity was still present after 4 h.

The remaining polystyrene packing materials and package had little or no ^{133}Xe contamination detected by imaging or monitoring. The next day, no contamination could be detected by imaging or monitoring of any of the polystyrene packing materials that remained unsealed in the fume hood overnight.

The ^{133}Xe vial that apparently leaked activity during shipping continued to loose activity after it was received. Based on its

initial assay in the dose calibrator, subsequent assays demonstrated this loss (Fig. 4). The percent difference from the expected activity over time was -1.6% , -6.4% , -14.2% , -17.0% and -18.9% at 0.3 d, 2.2 d, 7.0 d, 10.0 d and 11.3 d, respectively. There was no evident problem (e.g., improper placement of the rubber stopper, damaged metal crimp seal, crack in the glass vial) with the ^{133}Xe vial that could account for

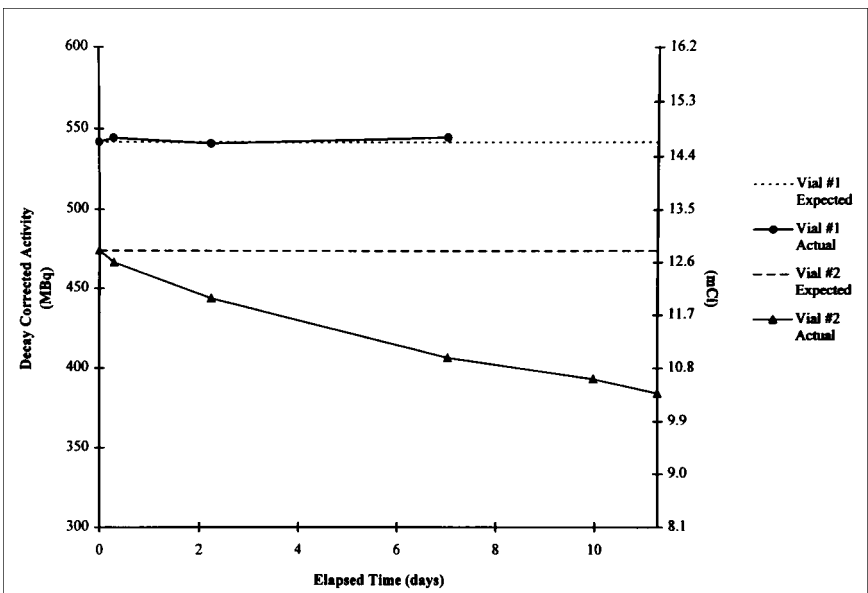


FIGURE 4. Decay-corrected activity of both ^{133}Xe vials over time while being stored in a fume hood until use. The vial that apparently leaked during shipping (i.e., vial 2 with the lower initial activity) continued to leak while the other vial did not.

the leakage. The other ^{133}Xe vial demonstrated no loss of activity over time (percent difference ranged from -0.2 – 0.6% at 0.3 – 7.0 d).

DISCUSSION

The use of ^{133}Xe gas for lung ventilation studies has been a vital part of nuclear medicine for many years. Safe handling and use of ^{133}Xe during these studies are essential to minimize radiation exposure to staff and the general public (1–2). There are several techniques described to monitor ^{133}Xe air contamination that results from this use (3–5). Consistent ^{133}Xe contamination found in the plastic tubes used by 1 manufacturer to house their shielded ^{133}Xe vials has been reported (6). This contamination was due to the expected leakage of 1–2% of the total activity from the vials according to its manufacturer. The leakage from our ^{133}Xe vial (different manufacturer than in reference 6) was approximately 16% of the expected activity at the time of receipt, and it continued to leak ^{133}Xe .

Although we are not required to monitor exposure levels of most incoming packages containing radioactive materials (< Type A quantities), according to NRC regulations (Title 10 Code of Federal Regulations 20.1906), we do because it is one of our NRC license conditions (7–8). During monitoring of this package, it was initially thought that the higher surface exposure reading was due to additional ^{133}Xe vials that might have been ordered, or that the placement of the vials within the polystyrene packing materials may have been different (e.g., placed on the outside holes rather than the center holes). The surface exposure levels were still below the US Department of Transportation (DOT) limits (Title 49 Code of Federal Regulations 172.403) for its DOT Radioactive Yellow II label (i.e., maximum surface radiation level of 0.5 mSv/h). The exposure level at 3 m from the package was below its labeled transport index (TI) of 0.1 mrem/h (1.0 $\mu\text{Sv/h}$). After finding only 2 ^{133}Xe vials in their normal placement in the packing materials, and then assaying them and seeing a difference in activity in each vial, it became evident that there was another reason for the increased surface exposure. Monitoring the packing materials confirmed that the increased surface exposure was due to ^{133}Xe contamination in the polystyrene packing materials. One would probably not expect contamination of packing materials and containers used to house radioactive gases during shipping but this report and another (6) have demonstrated that it is possible. Packing materials and containers that house ^{131}I shipments have been reported (9–11) to be contaminated with ^{131}I and its radioactive daughter, $^{131\text{m}}\text{Xe}$ gas.

The manufacturer was notified of the problem with the contaminated packing materials caused by the leakage of the

^{133}Xe vial, and the continued leakage of the vial after receipt. They stated that occasionally (every 3–4 mo) they do have reports of ^{133}Xe vials that leak (Moser L, *personal communication*, 1998). We have not experienced leakage of a ^{133}Xe vial since the event reported here.

CONCLUSION

This incident demonstrates that radioactive contamination of packing material from a ^{133}Xe shipment is possible. Monitoring with a survey meter is the definitive step to determine if the packing materials are contaminated before their disposal. Higher external package radiation levels than expected can be a sign that contamination of packing materials may be present. This knowledge will allow the surveyor to take action (e.g., open package in a fume hood) to minimize radiation exposure of themselves and fellow staff members if the packing materials are truly contaminated with ^{133}Xe . The immediate assay of each ^{133}Xe vial will indicate (i.e., lower activity than expected) if any leakage of radioactive gas has occurred. If leakage is detected, the packing materials can be placed in a fume hood, or sealed tightly in plastic bags if a fume hood is unavailable, to minimize exposure. Knowing a ^{133}Xe vial has leaked activity, there is a potential that it is still leaking. The leaking ^{133}Xe vial should be stored in a fume hood until it can be used to minimize radiation exposure of staff members. We recommend that the vial be used for the next ventilation study.

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