Radioactivity Decontamination of Materials Commonly Used as Surfaces in General-Purpose Radioisotope Laboratories

Natalia M. Leonardi, Fiorella C. Tesán, Marcela B. Zubillaga, and María J. Salgueiro

Radioisotope Laboratory, Physics Department, School of Pharmacy and Biochemistry, University of Buenos Aires, Buenos Aires, Argentina

In accord with as-low-as-reasonably-achievable and good-manufacturing-practice concepts, the present study evaluated the efficiency of radioactivity decontamination of materials commonly used in laboratory surfaces and whether solvent spills on these materials affect the findings. **Methods:** Four materials were evaluated: stainless steel, a surface comprising one-third acrylic resin and two-thirds natural minerals, an epoxy cover, and vinyl-based multipurpose flooring. Radioactive material was eluted from a ^{99}Mo/^{99m}Tc generator, and samples of the surfaces were control-contaminated with 37 MBq (100 µL) of this eluate. The same procedure was repeated with samples of surfaces previously treated with 4 solvents: methanol, methyl ethyl ketone, acetone, and ethanol. The wet radioactive contamination was allowed to dry and then was removed with cotton swabs soaked in soapy water. The effectiveness of decontamination was defined as the percentage of activity removed per cotton swab, and the efficacy of decontamination was defined as the total percentage of activity removed, which was obtained by summing the percentages of activity in all the swabs required to complete the decontamination. **Results:** Decontamination using our protocol was most effective and most efficacious for stainless steel and multipurpose flooring. Moreover, treatment with common organic solvents seemed not to affect the decontamination of these surfaces. Decontamination of the other two materials was less efficient and was interfered with by the organic solvents; there was also great variability in the overall results obtained for these other two materials. **Conclusion:** In expanding our laboratory, it is possible for us to select those surface materials on which our decontamination protocol works best.

Key Words: radioactivity decontamination; ^{99m}TcO$_4$Na; current good radiopharmacy practices

J Nucl Med Technol 2014; 42:292–295
DOI: 10.2967/jnmt.114.144303

Dealing with open sources of radioactivity in the radiopharmacy is a daily task. For that reason, contamination due to radioactive spills may be as frequent as or more frequent than in other areas of the nuclear medicine department or other radioactive facilities (*1*). The main consequences of contamination of the radiopharmacy working surfaces are an increase in the radiation exposure of personnel (*2,3*) and the possibility that their hands, face, and outer clothing will be contaminated (*4–6*). Furthermore, such external contamination may allow radioactive material to enter the systemic circulation and then be taken up by organs. In addition, the contamination of surfaces is an important issue because it may facilitate cross contamination of reactive products handled in the radiopharmacy. Therefore, contamination constitutes a risk to the health of exposed workers and its removal is the most straightforward approach to reducing such a hazard. Nuclear and health regulations reinforce the requirements for decontamination and cleaning procedures based both on principles of radiation protection, such as ALARA (as low as reasonably achievable), and good manufacturing and laboratory practices (*7–12*).

Several formulations for decontamination are commercially available and have been evaluated for their relative efficiency on the skin and on surfaces such as personnel clothing, patient beds, and vinyl-based flooring (*13–16*). Nevertheless, validation of the qualifications of various surface materials for inclusion in the design of a radiopharmacy is a step forward in accomplishing the objectives of ALARA and good manufacturing practices.

The present study was conducted to select the materials for the workbenches and flooring of a general-purpose radioactive laboratory dedicated mostly to compounding and quality control of ^{99m}Tc-radiopharmaceuticals. The Department of Maintenance and Infrastructure of the School of Pharmacy and Biochemistry of the University of Buenos Aires offered us samples of commonly used laboratory-surface materials on which to evaluate the efficiency of radioactivity decontamination. We also evaluated whether spills of solvents commonly used in mobile phases for chromatographic quality control of ^{99m}Tc-radiopharmaceuticals may modify the performance of decontamination.

MATERIALS AND METHODS

Reagents and Materials

^{99m}Tc-sodium pertechnetate was obtained from elution of a ^{99}Mo/^{99m}Tc generator (Laboratorios Bacon SAIC). The decontamination formulation was prepared by adding a commercial neutral

---

Received Jun. 10, 2014; revision accepted Sep. 17, 2014.

For correspondence or reprints contact: María J. Salgueiro, University of Buenos Aires, Junin 956 Piso Bajo (1113), Buenos Aires, Argentina.
E-mail: jsalgueiro@ffyb.uba.ar.

Published online Oct. 23, 2014.
COPYRIGHT © 2014 by the Society of Nuclear Medicine and Molecular Imaging, Inc.

cleaning agent (Cif Active Gel; Unilever) to water for a final aqueous solution of 10% v/v. Candidate surface materials were provided as 10 × 10 cm samples that had not previously been used for any purpose. These materials included stainless steel suitable for sinks and workbenches, a workbench surface comprising one-third acrylic resin and two-thirds natural minerals (Corian; DuPont), an epoxy cover intended both for workbenches and flooring, and vinyl-based multipurpose flooring.

Radioactivity was measured using a dose calibrator (Vexcal), a γ well–type counter (Alfanuclear), and a Geiger–Müller survey meter with a pancake probe (Alfanuclear).

Contamination Protocol

Three days before the contamination, quadruplicate samples of each kind of surface were treated with methanol, methyl ethyl ketone, acetone, and ethanol over a 3 × 3 cm area and allowed to air-dry. One sample of each surface was not treated and served as a control. For the contamination, freshly eluted ^{99m}Tc-sodium pertechnetate was deposited on a delimited 2 × 2 cm patch using an automatic pipette in 100-μL aliquots containing 37 MBq (1 mCi) each, previously measured in a dose calibrator. All contaminated material was allowed to air-dry for 3 d.

Decontamination Protocol

The contamination was removed using cotton swabs (0.5-cm diameter; Johnson and Johnson) soaked and wringed out in the decontamination solution. Decontamination was attempted by 4 different operators to obtain quadruplicates, and each attempt was performed for 1 min from the outside to the inside of the delimitated area. After each attempt, radioactivity in the cotton swab was measured in a calibrated γ well–type counter, and residual contamination on surfaces was monitored with a survey meter. Decontamination attempts were repeated until the activity removed was equivalent to background radioactivity or until the percentage of activity removed (%AR) was less than 1% on 3 consecutive attempts. The results of cumulated %AR for 1, 5, and 10 cotton swabs are shown in Table 1.

Data Analysis

The effectiveness of decontamination was defined as the percentage of activity removed per cotton swab, calculated using the following formula: %AR = (activity removed in the cotton swab/total contamination activity) × 100. The efficacy of decontamination was defined as the total %AR removed, which was obtained by summing the %AR in all the swabs required to complete the decontamination. The number of cotton swabs was also recorded.

Statistical Analysis of Decontamination Efficacy

Decontamination for each group was performed in quadruplicate, and the results are expressed as the mean and SD of these 4 attempts. One-way ANOVA with a significance level of 0.05 was used to compare data.

RESULTS

The efficacy of decontamination of each type of treated and untreated surface is shown in Figure 1. The contribution of just the first cotton swab to total decontamination is also shown. In the case of stainless steel, most (>80%) of the contamination was removed independently of treatment with solvents and with use of fewer cotton swabs than for the other materials (Table 1). Contamination was removed from stainless steel in only 2 attempts when it was not treated with solvents or was treated with methyl ethyl ketone, and more than 80% was removed in less than 5 attempts when it was treated with the other solvents. The other surface materials were less effectively and efficaciously decontaminated than stainless steel; total and partial cumulative values of %AR (Table 1) were lower for all of them. The most striking finding, especially in the case of the acrylic resin–natural mineral surface, was large SDs caused by marked variability in the results (Fig. 1). This interfered with the statistical interpretation, since the large SDs resulted in no significant differences in mean efficacy as calculated by ANOVA. Vinyl-based multipurpose flooring demonstrated an acceptable efficacy for decontamination, although only after at least 5 attempts. Like stainless steel, decontamination of vinyl-based multipurpose flooring seemed unaffected by treatment with solvents, since there were no differences in efficacy among its groups. The acrylic resin–natural mineral surface and the epoxy cover showed great variability in performance for total and partial cumulative %AR among samples treated or not with solvents (Fig. 1; Table 1). It seems that the solvents improved decontamination of the acrylic resin–natural mineral surface but impaired decontamination of the epoxy cover, with no apparent common pattern for the action of the solvents on these 2 types of surfaces.

TABLE 1

Cumulative Effectiveness of Radioactivity Decontamination

		%AR			
Solvent	Cotton swabs (*n*)	SS	C	M	E
None	1	88.4	38.3	52.6	48.3
	5	100 (2)	50.7	80.6	71.5
	10	—	53.1	86.3	79.3
MeOH	1	78.3	48.2	56.9	32.4
	5	82.8	72.6	82.9	45.6
	10	82.8	90.0	88.8	48.8
MEK	1	95.8	79.6	38.7	63.4
	5	100 (2)	97.3	67.3	71.8
	10	—	97.9	77.2	72.8
Acetone	1	96.6	34.7	46.4	35.0
	5	98.0	56.0	84.6	47.1
	10	98.5	61.8	91.1	50.4
EtOH	1	75.2	47.8	47.4	31.7
	5	80.5	61.5	77.3	45.5
	10	89.5	64.3	84.6	49.2

SS = stainless steel; C = Corian surface (acrylic resin and natural minerals); M = vinyl-based multipurpose flooring; E = epoxy cover; MEK = methyl ethyl ketone.

Data are mean of 4 replicates. %AR is percentage of initial activity. Data in parentheses are number of cotton swabs used for removal when 100% was removed earlier.

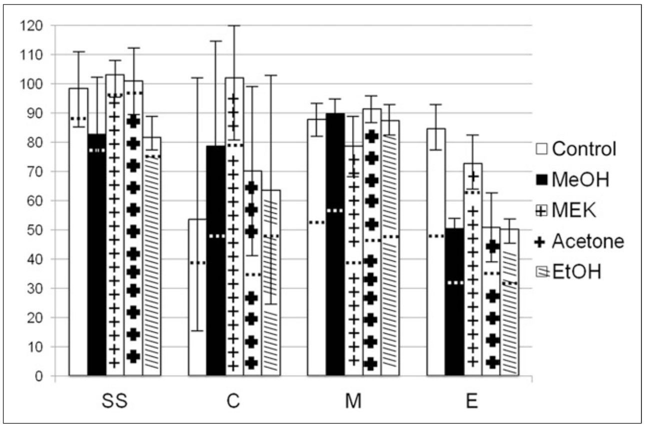

FIGURE 1. Decontamination efficacy as total %AR for working-surface materials both treated and untreated with common organic solvents. Results are shown as mean of 4 replicates for each group, and contribution of first cotton swab to total %AR is indicated by dashed line in each column. C = Corian surface (acrylic resin and natural minerals); E = epoxy cover; M = vinyl-based multipurpose flooring; MEK = methyl ethyl ketone; SS = stainless steel.

DISCUSSION

This work assayed the efficacy of decontamination of 4 materials for working surfaces in a general-purpose radioisotope laboratory: stainless steel, an acrylic resin–natural mineral surface, an epoxy cover, and vinyl-based multipurpose flooring. This work also investigated whether decontamination is modified by spills of 4 solvents commonly used in the mobile phase for chromatographic quality control of ^{99m}Tc-radiopharmaceuticals: methanol, methyl ethyl ketone, acetone, and ethanol. The goal of these investigations was to determine which surfaces would best meet ALARA and good-manufacturing-practice requirements in the design of an expansion of our laboratory. The results showed that decontamination of stainless steel was most efficacious and most effective and was not affected by treatment with the solvents. Therefore, stainless steel was selected for the workbenches and sinks of our laboratory. Decontamination of vinyl-based multipurpose flooring also demonstrated excellent efficacy and was barely affected by the solvents; such flooring was therefore our choice.

Decontamination of the vinyl-based multipurpose flooring was less effective than that for stainless steel; more attempts were required to achieve decontamination, although five seemed enough. The other materials were discounted as candidates—the epoxy cover because of lower efficiency combined with interference by the solvents, and the acrylic resin–natural mineral surface because of great variability in the results. The findings for both these materials suggest that decontamination efficacy may not be acceptable even after numerous attempts, and radiation exposure to staff may therefore be increased either because of the duration of the decontamination process or high residual contamination. The reason for the unacceptable efficacy in these materials is not fully understood but is hypothesized to be due to inconsistencies in the wiping method by different operators (exact motion and pressure during each wipe) combined with some characteristic of the material (although new surface samples were used). Similar results and analyses were reported by Ruhman et al. (*15*) for Formica laminate and vinyl tile.

This work deals with radioactive contamination with ^{99m}Tc in the chemical form of sodium pertechnetate (Na^{99m}TcO$_4$). Pertechnetate is the radioactive precursor of ^{99m}Tc-radiopharmaceuticals routinely used in nuclear medicine, and the radioactivity from column generators is much higher than that from individual radiopharmaceuticals. It seemed a rational approach to start the protocol with pertechnetate. Nevertheless, it is remarkable that, on the other hand, pertechnetate is chemically inert unless the formulation contains reducing agents. That is why any fixed contamination observed with this compound would be caused by the porosity of the material or by some unknown chemical bond raised by the surface of the material. Thus, the results cannot be extrapolated to other ^{99m}Tc-compounds or ^{99m}Tc-radiopharmaceuticals because chemical behavior is not predictable. Similar protocols should be performed to assess the results for these other compounds.

CONCLUSION

Dealing with unsealed radioactive sources in the radiopharmacy or the radioisotope laboratory is a daily challenge. The radiopharmacy staff requires not only expertise in pharmaceutical formulation, compounding, preparation, and control but also skill in managing radioactive material. Accordingly, the staff members must be familiar with the ALARA concept and with the good manufacturing and laboratory practices specific to their work. It is therefore important to set up protocols to manage contamination of workers, patients, or materials and equipment and to be able to make the best selection of materials for building or remodeling the laboratory. Through our study, we were able to select the best materials for the workbenches and floor of our laboratory, according to the findings for our decontamination protocol.

DISCLOSURE

This work was financially supported by project UBACYT 20020100300071 from the University of Buenos Aires. No other potential conflict of interest relevant to this article was reported.

REFERENCES

1. Heller SL. Radiation safety in the central radiopharmacy. *Semin Nucl Med.* 1996;26:107–118.
2. Meineke V, Van Beuningen D, Sohns T, Fliender T. Medical management principles for radiation accident. *Mil Med.* 2003;168:219–222.
3. Rojavin Y, Seamon MJ, Tripathi RS, et al. Civilian nuclear accidents: an overview of historical, medical, and scientific aspects. *J Emerg Trauma Shock.* 2011;4:260–272.

4. Tazrart A, Bérard P, Leiterer A, Ménétrier F. Decontamination of radionuclides from skin: an overview. *Health Phys.* 2013;105:201–207.
5. Schofield G. Radioactive contamination of the skin. *J Soc Cosmet Chem.* 1971;22:535–545.
6. Nishiyama H, Van Tuinen RJ, Lukes SJ, Feller PA. Survey of ^{99m}Tc contamination of laboratory personnel: hand decontamination. *Radiology.* 1980;137:549–551.
7. Norma básica de seguridad radiológica (AR 10.1.1, revision 3). Autoridad Regulatoria Nuclear website. http://www.arn.gov.ar/images/stories/que_hace_la_ARN/resena_de_actividades/marco_regulatorio/normas_regulatorias/10-1-1_R3.pdf. Accessed September 19, 2014.
8. Uso de fuentes radiactivas no selladas en instalaciones de medicina nuclear (AR 8.2.4, revision 1). Autoridad Regulatoria Nuclear website. http://www.arn.gov.ar/images/stories/que_hace_la_ARN/resena_de_actividades/marco_regulatorio/normas_regulatorias/8-2-4_R1.PDF. Accessed September 19, 2014.
9. Apruébanse los lineamientos generales de buenas prácticas de fabricación para elaboradores, importadores/exportadores de medicamentos (disposición ANMAT N° 2819/2004). http://www.anmat.gov.ar/webanmat/Legislacion/Medicamentos/Disposicion_2004_2819.pdf. Accessed September 19, 2014.
10. *Norma IRAM 9800-4 Buenas Prácticas Farmacéuticas: Parte 4-Radiofármacos.* Buenos Aires, Argentina: Instituto Argentino de Normalización y Certificación (IRAM); 2011.
11. Elsinga P, Todde S, Penuelas I, et al. Guidance on current good radiopharmacy practice (cGRPP) for the small-scale preparation of radiopharmaceuticals. *Eur J Nucl Med Mol Imaging.* 2010;37:1049–1062.
12. Duatti A, Bhonsle U. Strengthening radiopharmacy practice in IAEA Member States. *Semin Nucl Med.* 2013;43:188–194.
13. Moore PH, Mettler FA. Skin decontamination of commonly used medical radionuclides. *J Nucl Med.* 1980;21:475–476.
14. Bolzinger MA, Bolot C, Galy G, et al. Skin contamination by radiopharmaceuticals and decontamination strategies. *Int J Pharm.* 2010;402:44–49.
15. Ruhman N, Vesper G, Martin C. The effectiveness of decontamination products in the nuclear medicine department. *J Nucl Med Technol.* 2010;38:191–194.
16. Rana S, Bhatt S, Dutta M, et al. Radio-decontamination efficacy and safety studies on optimized decontamination lotion formulation. *Int J Pharm.* 2012;434:43–48.