BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
11-01A (2023) | 01-18 | e2187

SBPR
Sociedade Brasileira de Proteção Radiológica

Effectiveness of polymeric gloves in radioprotection against contamination in nuclear medicine

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ABSTRACT

When handling unsealed radioactive sources, radiological protection attention must be taken to avoid unnecessary exposure and radioactive contaminations, and an important and necessary practice to prevent such contaminations is the use of gloves when handling these sources. The present work aimed to determine the effectiveness of contamination protection provided by different types of disposable polymeric gloves used in Nuclear Medicine Service in Clinic Hospital of Porto Alegre, testing the main radiopharmaceuticals used at this site: [^{99m}Tc]sodium pertechnetate, [^{18}F]FDG and [^{131}I]sodium iodide. The analysis was performed using the wipe test inside gloves intentionally contaminated on the outside with these radiopharmaceuticals. The radiation detector used to measure the contamination was a NaI(Tl) scintillator well-type counter. The results indicate that three types of gloves analyzed protect the user from [^{99m}Tc]sodium pertechnetate and [^{18}F]FDG contamination, for permanence times with the glove after contamination for up to 15 min (interval tested). For [^{131}I]sodium iodide, gloves are completely effective in protection as long as they are used for a time interval after contamination of the external surface of up to: Latex – 5 min; Vinyl – 5 min; Nitrile – 10 min. Among them, the nitrile glove are the most effective, since contamination was not observed on the inner face for times equal to or less than 10 min; and, for an interval of 15 min, the percentage of permeation obtained was lower than the other two types: 3.3 times lower than vinyl glove permeation and 1.3 times lower of the latex glove permeation. It was also possible to estimate the skin dose rate due to contamination caused by iodine permeation for each glove case and time tested.

Keywords: **permeation, radioactive contamination, radiological protection.**

ISSN: 2319-0612
DOI: https://doi.org/10.15392/2319-0612.2023.2187
Submitted: 2022-11-29
Accepted: 2023-03-21

1. INTRODUCTION

The use of personal protective equipment is essential in good practices for handling radioactive material. In particular, when handling unsealed sources, the use of gloves is essential to prevent hand contamination. However, it is necessary to the gloves to be efficient in this protection, being made of suitable material to prevent the permeation of radioactive material by them. Investigations [1,2] indicate that not all types of gloves are effective in protecting against radioactive contamination. In Brazilian normative, the use of disposable gloves is mandatory, however, there is no indication of the composition of gloves [3-5], indicating that any glove in good condition could be used in the practice of handling unsealed radioactive sources.

This study aimed to determine the protection efficiency of different types of disposable gloves available at Nuclear Medicine Service (NMS) of Clinic Hospital of Porto Alegre (Hospital de Clínicas de Porto Alegre, HCPA in Portuguese) against radioactive contamination of the hands of workers responsible for handling radioactive unsealed sources. The objective was to analyze the possibility of permeation of radiopharmaceuticals [^{131}I]sodium iodide, [^{99m}Tc]sodium pertechnetate and [^{18}F]fludeoxyglucose (FDG), all in aqueous solution, through disposable gloves. Therefore, it was analyzed the possibility of contamination of the worker's hands while handling the material, even if they have correctly followed the radiation protection instructions for good practices in handling radioactive material, including the use of disposable gloves.

In the case of permeation, and therefore contamination, the aim was to quantify it in terms of permeation percentage and estimate values of radiation dose rate on the skin of the contaminated individual's hands. In addition, this research aimed to determine the influence of the time spent with gloves after contamination on the permeation percentage.

2. MATERIALS AND METHODS

As a permeation detection method, the wipe test was performed in the inside of the gloves purposely contaminated with radioactive material in its external face. The wipe test consists of rubbing an absorbent material, such as paper, fabric, cotton, etc., on a surface and then measuring the activity of the absorbent material, in order to estimate the removable activity on this surface [6].

2.1. Materials

The materials used in data collection are presented below:

2.1.1 Gloves

Three different types of gloves were tested, arranged in Table 1.

Table 1: Tested gloves and their respective specifications.

Glove type (material)	Manufacturer tested	Batch tested	Manufacturing date	Expiration date
Vinyl	DESCARPACK	SVFJAA087M	March/2021	March/2026
Latex	LEMGRUBER	PR020K	October/2020	October/2025
Nitrile	SUPERMAX	009683	April/2020	April/2025

2.1.2 Radionuclides

The radionuclides tested are shown in Table 2, and were selected once they are the three most used types in the service in question, in addition to being widely applied in the practice of nuclear medicine. The activity concentration was adjusted with the available radioactive material destined for equipment quality control and research.

Table 2: Tested radiopharmaceuticals and their specifications.

Radionuclide	Chemical Form	Form	Activity Concentration
^{99m}Tc	sodium pertechnetate	Aqueous solution	185 MBq/mL (5 mCi/mL)
^{18}F	FDG		
^{131}I	sodium iodide		

2.1.3 NaI(Tl) Scintillator Well-type Counter

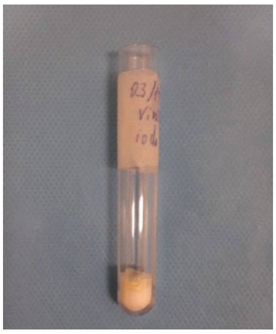
The detector used to count the activity of the samples obtained in the wipe test was a NaI(Tl) scintillator well-type counter CAPTUS 3000 system (Capintec, USA) [7].

2.2. Methods

2.2.1 Detection Efficiency

To convert the counts per minute (cpm) measured in NaI(Tl) scintillator well-type counter to activity contained in the sample it was necessary to determine the detector's efficiency for the radionuclides analyzed. For each radionuclide, a radioactive source was used, whose activity was determined using the Capintec CRC-25 PET Dose Calibrator (used for measuring radiopharmaceuticals activities in the HCPA's NMS), as a reference. The sources were made in such a way that their geometry was the same as that used in the wipe test: cotton with radioactive material, inserted into a plastic test tube (Figure 1).

Figure 1: Photograph of a sample.



Once the aim is to obtain the percentage of permeation, the accuracy of the dose calibrator is not relevant, once the activity permeated per activity deposited (see equation 5) will result in independence of correction factors (as geometry factors, for example) as long as all measures with the dose calibrator are made with the same conditions and the equipment presents reproducibility between its measures, since all the activities estimated are correlated to it. All the quality control tests [5] necessary to ensure the correct performance of the equipment was updated, and the equipment has traceability with the National Laboratory of Metrology of Ionizing Radiation (ARCAL RLA 6074/2016).

The Efficiency value E_{ff} is obtained by equation (1), where C_{ref} and A_{ref} are respectively the counts and the activity of a radioactive source used as a reference.

$$\mathrm{E_{ff}} = \frac{\mathrm{C_{ref}}}{\mathrm{A_{ref}}} \tag{1}$$

Counts from each source were determined using the NaI(Tl) scintillator well-type counter detector in acquisitions during 600 seconds. Table 3 presents the values of the activities of the sources used as reference (measured with the dose calibrator), the counts per minute obtained (using the CAPTUS 3000 well-type counter) and their respective measurement time, for possible decay corrections.

Table 3: Activity values and measured counts per minute of each source used as a reference to determine the efficiency of the NaI(Tl) scintillator well-type detector, for each radionuclide used.

Nuclide	Activity $\mathrm{A_{ref}}$ (kBq)	Measurement time	$\mathrm{C_{ref}}$ (cpm)	Measurement time
^{99m}Tc	288 ± 4	4:43 pm	$(460.8 \pm 0.2) \times 10^3$	4:48 pm
^{18}F	448 ± 4	3:03 pm	$(1.16 \pm 0.01) \times 10^6$	3:07 pm
^{131}I	237 ± 4	5:38 pm	$(391.8 \pm 0.2) \times 10^3$	5:45 pm

2.2.2 Minimum detectable activity

The minimum detectable activity (MDA) is defined as the lowest radionuclide activity that can be reliably determined [8]. Any activity below this value it was considered as an activity equal to zero. The MDA depends on the background radiation value in the energetic region of interest and on the acquisition time. To determine this parameter three acquisitions of background radiation were performed without the presence of radiation sources in the measurement environment. The MDA calculation [9] used is shown below in equation (2).

$$\mathrm{MDA} = \frac{\mathrm{f}\sqrt{\mathrm{C_{BG}} + \mathrm{K}}}{\mathrm{E_{ff}}.\,\mathrm{T}} \tag{2}$$

where the precision factor f is equal to 4.65; the K correction factor equal to 2.71 [10]; $\mathrm{E_{ff}}$ the detection efficiency for each radionuclide; $\mathrm{C_{BG}}$ equals the means of the counts obtained in the three background radiation acquisitions (values of Table 10); and T the counting time, equal to 600 s (the same for all samples of the wipe test).

2.2.3 Wipe Test

The procedures performed for the preparation of each wipe test sample are described below.

- Step 1 - Preparation of Radioactive Material:

A 1 mL syringe was prepared with the aqueous solution containing the radionuclide of interest, at a concentration of 185 MBq/mL (5 mCi/mL).

- Step 2 - Positioning the Glove:

The glove was positioned on an adapted support (Figure 2) using a radiopharmaceutical shield simulating stretching in the palm of the wearing glove. Before putting on the glove, the support was wrapped in several layers of plastic film, which was replaced with each glove test to avoid cross-contamination.

Figure 2: Support used for the wipe test.

- Step 3 - Activity Measurement:

The activity in the syringe A_a was measured using the activity meter, registering the activity values and also the hour and minute of the measurement.

- Step 4 - Contamination of Gloves:

The deposition of 1 drop (0.05 mL) of the radioactive solution, prepared in step 1, on the external surface of the gloves was performed with the syringe (without needle). From that moment on, a timer programmed with the desired intervals for analysis after contamination was activated (15, 10, 5 or 2 minutes, according to the radionuclide).

- Step 5 - Remaining Activity Measurement:

The remaining activity A_d in the syringe was measured using the dose calibrator. The activity values as well as the hour and minute of measurement were recorded.

- Step 6 - Wipe test:

After the end of the timer, according to the specific time for each case, the glove was removed from the support and a cotton was rubbed on the inside of the glove in the region corresponding to the reverse side of the contamination (inside). Continuous movements were performed in the same direction, totaling ten movements. The cotton used was placed inside a plastic test tube (Figure 1) and counted in the NaI(Tl) scintillator well-type detector for 600 seconds.

Measurements of the samples were initiated with the longest time interval (longest time spent with the same pair of gloves by the worker, 15 min) for each radionuclide. If the result indicated permeation of the radionuclide to the inner face of the glove, shorter time intervals would be tested. The only radiopharmaceutical that was necessary to use shorter times was the one with ^{131}I, reaching the shortest time of 2 min (the minimum average time estimated of permanence in routine). With the test, the values of counts per minute detected C in each sample were obtained. Considering that tests were carried out from the longest time until obtaining undetectable permeability, for the different radionuclides and different gloves tested, 16 different samples of gloves tested were necessary.

The Material Safety Data Sheet provided by the manufacturer informs that the [^{131}I]sodium iodide solution has a pH between 9.0 and 12.0 [11]. However, the radiopharmaceutical description leaflet also informs that the pH of the solution can be reduced as a result of dilution of the solution [12]. In order to estimate the pH of the solution used in this study, which has been diluted, a solution of the same volume and activity concentration used in the tests was prepared reproducing the one used in the tests. Through the use of the colorimetric paper pH indicator, the pH of the solution was determined as $pH = 5.5$.

2.2.4 Permeability of Disposable Gloves

To determine the percentage of permeation that occurred in disposable gloves, it was necessary to determine the ratio between the activity values on the inner/outer faces of the gloves. The activity deposited on the outside of each tested glove ($\mathrm{A_{dep}}$), through the deposition of a drop on its surface, was determined from equation (3):

$$\mathrm{A_{dep}} = \mathrm{A_a} - \mathrm{A_d} \tag{3}$$

All measurement pairs ($\mathrm{A_a}$ and $\mathrm{A_d}$, for each glove) were performed in a time interval less than or equal to two minutes and therefore, decay effects were disregarded for the calculations of $\mathrm{A_{dep}}$ for the ^{99m}Tc (half-life of 6,01 hours) and ^{131}I (half-life of 8,03 days) cases. The values of $\mathrm{A_d}$ for ^{18}F case were corrected for the time interval between their measurement and the measurement of $\mathrm{A_a}$, $\mathrm{A_d[corr.]}$ duo to its short half-life.

The results $\mathrm{A_{dep}}$ are in Table 4 (^{99m} Tc), Table 5 (^{18} F) and Table 6 (^{131} I). The variation between deposited activities presented is given by the lack of precision in the mechanism of deposition of the droplet of radioactive material; however, this should not be a factor of concern, since the determination of the percentage of permeation is independent of the absolute activity deposited.

Table 4: Activity deposited ($\boldsymbol{A_{dep}}$) for each type of glove, 15 min after contamination, for ^{99m}Tc.

Glove type	$\mathbf{A_{dep}}$(MBq)
Vinyl	6.3 ± 0.4
Nitrile	8.9 ± 0.4
Latex	8.5 ± 0.4

Table 5: Activity deposited ($\boldsymbol{A_{dep}}$) of ^{18}F for each type of glove and time intervals between measurements (Δt).

Glove type	$\mathbf{A_a}$(MBq)	$\mathbf{A_d}$(MBq)	$\mathbf{\Delta t}$(min)	$\mathbf{A_d[corr.]}$(MBq)	$\mathbf{A_{dep}}$(MBq)
Vinyl	45.5 ± 0.4	36.3 ± 0.4	1 ± 1	36.6 ± 0.4	8.9 ± 0.4
Nitrile	46.5 ± 0.4	34.8 ± 0.4	2 ± 1	35.2 ± 0.4	11.5 ± 0.4
Latex	46.3 ± 0.4	38.1 ± 0.4	2 ± 1	38.5 ± 0.4	7.8 ± 0.4

Note: $\mathbf{A_a}$= activity in the syringe; $\mathbf{A_d}$= residual activity in the syringe; $\mathbf{A_d[corr.]}$= residual activity in the syringe after radioactive decay correction.

Table 6: Activity deposited ($\boldsymbol{A_{dep}}$) of ^{131}I for each type of glove and time intervals after contamination.

		$\mathbf{A_{dep}}$(MBq)			
Time after contamination (min)		**2**	**5**	**10**	**15**
glove type	**Vinyl**	-	9.6 ± 0.4	7.0 ± 0.4	6.7 ± 0.4
	Nitrile	-	8.5 ± 0.4	7.8 ± 0.4	8.5 ± 0.4
	Latex	7.0 ± 0.4	7.0 ± 0.4	8.5 ± 0.4	11.1 ± 0.4

Note: The 2-minute interval method was applied only for the latex glove, as this was the only case of activity detection in the 5 min time wipe test.

The amount of radioactive material that was permeated to the inner face of the glove was evaluated by determining the activity deposited on the cotton by the wipe test (A_e), using the correlation between the counts per minute (C) and the detection efficiency E_{ff} of the analyzed radionuclide through equation (1).

$$A_e = \frac{C}{E_{ff}} \tag{1}$$

Finally, the percentage permeation P_T (with the index T meanig that is associated with the time after contamination of the glove) was determined using equation (2).

$$P_T(\%) = \frac{A_e}{A_{dep}} \times 100. \tag{2}$$

2.2.5 Estimated Dose Rate in the Skin

To estimate the radiation dose received at the hands of a worker that becomes contaminated due to the permeation of the radionuclide in question, we can build an equation that relates the amount of radioactive material deposited on the surface of the glove to the radiation dose received on the skin. For a drop of [^{131}I]sodium iodide solution with a volume equal to 0.05 mL deposited on the skin (volume used in glove contamination), it is known that the dose rate received on the skin is 572 mSv/h for each MBq activity [13]. Therefore, taking into account the permeation percentage P_T, the skin of the hand of a worker that is contaminated with a drop (0.05 mL), will be exposed to a skin dose rate, $\dot{D}$(mSv/h), given by

$$\dot{D} = 572 \times P_T \times A \tag{3}$$

being A the drop activity in MBq and P_T the percentage permeation depending on the time after contamination (time that the worker has the contaminated glove on the hands) and the type of glove used.

If we consider a contamination with a [^{131} I]sodium iodide solution with a general concentration of $\phi\ MBq/mL$ in the external part of the gloves with a drop (0.05 mL) of this solution, it would have an activity deposited on the surface A equal to $A = 0{,}05\ \text{mL} \times \phi\ \text{MBq/mL} = 0{,}05\ \phi\ \text{MBq}$.

Using the equation (3), therefore, contaminations from the use of contaminated gloves would generate a dose rate on the skin of the hands of (Equation 4):

$$\dot{D}(mSv/h) = 28.6 \times \phi \times P_T. \tag{4}$$

In order to estimate and exemplify the dose rate in skin caused by iodine permeation, it was supposed a contamination with a drop (0,05 mL) of [^{131}I]sodium iodide solution available in NMS for therapy (7400 MBq) with a concentration of $\phi = 3733$ MBq/mL.

For contaminations with a major volume of solution, the skin dose rate could be estimated by superficial concentration φ ($MBq.cm^{-2}$) of the contamination solution. Also, dose rate per unit of area and activity equals to 1620 $(\mathrm{mSv/h})/(\mathrm{MBq.cm^{-2}})$ considering uniform deposition [13]. So, in case of major contamination, dose rate caused by skin contamination by permeation could be estimated by

$$\dot{D}(mSv/\,h\,) = 1620 \times \varphi \times P_T.$$

2.2.6 Uncertainties

For electronic equipment with digital display, such as the dose calibrator used, the uncertainty considered was the smallest unit of the scale used. For the NaI(Tl) scintillator well-type counter, as used in this work, the uncertainty (σ) of the count rate (cpm) was determined according to [14]:

$$\sigma = \sqrt{C} = \sqrt{\frac{\mathrm{Cont}}{t}} \tag{5}$$

being σ the estimated uncertainty and Count the number of counts obtained in the time interval t. For propagation of uncertainty, the equations shown in Table 7, for each case [15]:

Table 7: Uncertainty expressions used for each case.

$\mathbf{w = w(x, y, \ldots)}$, a = Constant	**Expressions for σ_w**
$w = a \pm y$ addition and subtraction	$\sigma_w^2 = \sigma_x^2 + \sigma_y^2$
$w = axy$ or $w = a\left(\frac{x}{y}\right)$ multiplication or division	$\left(\frac{\sigma_w}{w}\right)^2 = \left(\frac{\sigma_x}{x}\right)^2 + \left(\frac{\sigma_y}{y}\right)^2$
$w = ax$ Multiplication by constant	$\sigma_w = \lvert a \rvert \sigma_x$

All the values presented in the article preceded by +/- are type B uncertainties or propagation of this kind of uncertainties, and, therefore, can be interpreted as standard deviations of the respective average values [16].

3. RESULTS AND DISCUTION

3.1. Detection Efficiency

The determined values of E_{ff} calculated for each radionuclide analyzed are in Table 8, followed by its calculated uncertainties.

Table 8: NaI(Tl) scintillator Well-type counter detection efficiency determined for each radionuclide.

Radionuclide	^{99m}Tc	^{18}F	^{131}I
Efficiency E_{ff} (cpm/kBq)	15967 ± 3	25865 ± 22	16546 ± 3

3.2. Minimum Detectable Activity

Means for each radionuclide spectra region obtained from the three background acquisitions are showed in Table 9. The MDA values calculated for each radionuclide are shown in Table 10.

Table 9: Mean Counts obtained from background radiation (C_{BG}), in counts per minute (cpm), for each radionuclide tested.

Radionuclide	^{99m}Tc	^{18}F	^{131}I
C_{BG}*(cpm)*	293	425	420

Table 10: Minimum Detectable Activity (MDA) in Bq, for each radionuclide tested.

Radionuclide	^{99m}Tc	^{18}F	^{131}I
MDA (Bq)	0.48 ± 0.04	0.37 ± 0.04	0.59 ± 0.04

3.3. Wipe and Permeability Test

- [^{99m}Tc]sodium pertechnetate

For all gloves tested, no net counts per minute (cpm) above background radiation counts were detected in ^{99m}Tc photopeak (140 keV) for the 15 minutes post-contamination interval. For this reason, measurements were not acquired for shorter times, since these times would lead to equal or less permeated activity. As this is considered the longest permanence time during manipulation, it was determined that there is no permeation of radioactive material equal to or less than the MDA of ^{99m}Tc and, thus, it is considered that the three gloves were safe in handling [^{99m}Tc]sodium pertechnetate.

- [^{18}F]FDG

Likewise, as the last case, no net counts per minute (cpm) above background radiation counts were detected in ^{18}F photopeak (511 keV) for the 15 minutes interval after contamination. As this is considered the longest permanence time during manipulation, it was determined that there is no permeation of radioactive material equal to or less than the MDA of ^{18}F and, therefore, it is considered that the three gloves were safe in handling a solution of [^{18}F]FDG.

- [^{131}I]sodium iodide

Table 11 presents the values of net counts per minute (cpm) obtained in the NaI(Tl) scintillator well-type detector in the region of interest of the ^{131}I photopeak (364 keV). The values were automatically informed by the measurement system, already discounting the background radiation counts. In cases where net counts were not detected, the abbreviation “nd” was used, indicating non detection.

Table 11: Net counts per minute (C) obtained for each type of glove as a function of time after contamination for ^{131}I.

		Counts per minute (cpm)			
Time after contamination (min)		**2**	**5**	**10**	**15**
Glove type	**Vinyl**	-	nd	18 ± 1	34 ± 2
	Nitrile	-	-	nd	13 ± 1
	Latex	nd	10 ± 1	15 ± 1	22 ± 1

Applying the values of C in equation (1), the A_e values of for each type of glove were estimated as a function of the time interval after contamination of the glove, exposed in Table 12.

Table 12: Estimated activity for the interior of each type of glove, $\boldsymbol{A_e}$, as a function of time after contamination for ^{131}I.

		$\mathbf{A_e(Bq)}$			
Time after contamination (min)		**2**	**5**	**10**	**15**
Glove type	**Vinyl**	-	nd	$1.07 \pm 0{,}04$	2.1 ± 0.3
	Nitrile	-	-	nd	0.78 ± 0.07
	Latex	nd	0.59 ± 0.07	0.93 ± 0.04	1.33 ± 0.07

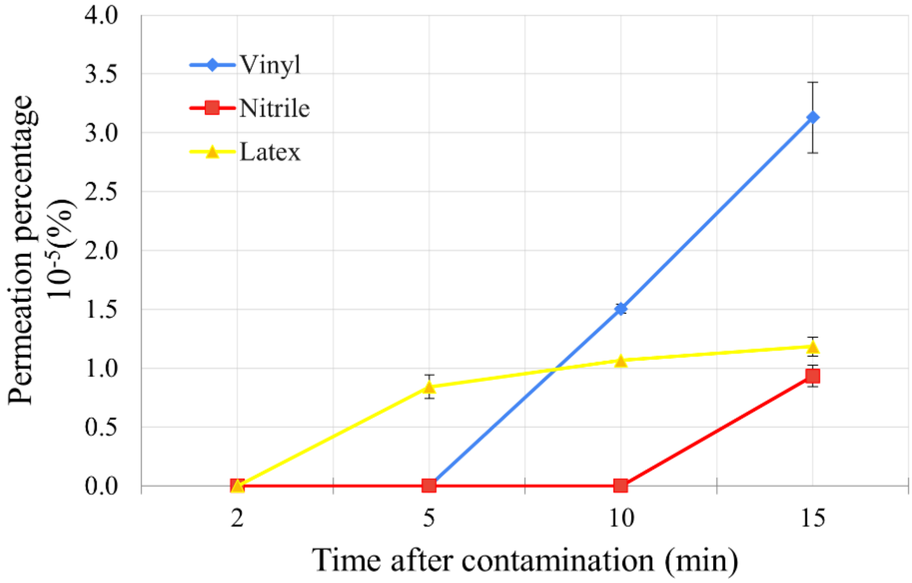
Using equation (2), the percentage of permeation P_T was determined, being the T index associated to the time after contamination of the glove. The values are displayed in Table 13 and represented in Figure 3.

Table 13: Percentage of permeation $\boldsymbol{P_T}$ of ^{131}I for each type of glove as a function of time after contamination.

		Percentage of permeation $\mathbf{P_T}$ $(\times \mathbf{10^{-5}}\ \%)$			
Time after contamination (min)		**2**	**5**	**10**	**15**
Glove type	**Vinyl**	-	nd	1.50 ± 0.09	3.1 ± 0.4
	Nitrile	-	-	nd	0.93 ± 0.09
	Latex	nd	$0.8 \pm 0{,}1$	1.07 ± 0.06	1.18 ± 0.08

Since the pH of the diluted solution used of [^{131}I]sodium iodide, estimated in $ph = 5{,}5$, should lead to an increase in the rate of iodine volatilization compared with the non-diluted radiopharmaceutical [17], it is important to notice that the estimated permeabilities may have been influenced by this factor, thus being one more variable to be investigated in further studies.

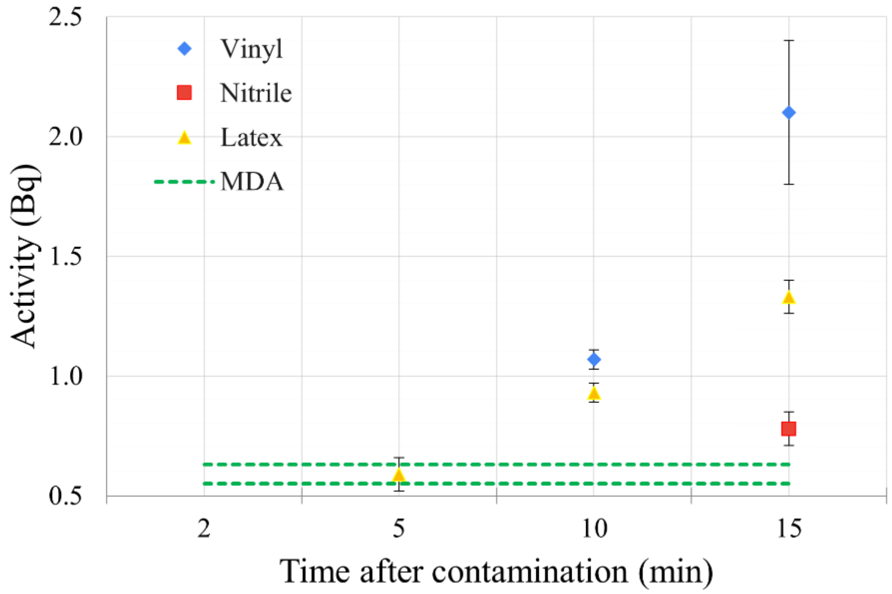
Figure 3: Graph of the percentage of permeation of ^{131}I as a function of time after contamination ($\boldsymbol{P_T}$).



3.4. Statistical Considerations

It is possible to make statistical considerations based on instrumental and propagated uncertainties, mainly with respect to the activity values detected inside the tested gloves (Table 13). For the case of the latex glove, note that the detected ^{131}I activity value for 5 min after contamination, considering its uncertainty, may be lower than the estimated minimum detectable activity value, as showed in Figure 4. In this case, therefore, there is no statistical security to guarantee that there was internal contamination of the latex glove observed for the case of 5 minutes after contamination and, therefore, it can be considered that all gloves showed total protection efficiency in up to this time of use after contamination with ^{131}I. For all other cases in which ^{131}I activity was observed inside the gloves, there is statistically significant confidence in identifying internal contamination considering the uncertainties. For all the cases that it was not observed contamination inside the gloves, including the tests with ^{99m}Tc and ^{18}F, it is secure to guarantee that it was no activity permeated major than the MDA added to its uncertainties.

Figure 4: Graph of the activity of ^{131}I detected inside the gloves as a function of time after contamination. The ^{131}I minimum detectable activity (MDA) was included in the form of dotted lines considering the uncertainty window.



3.5. Dose Rate

Table 14 displays the estimated dose rate for the different permeation percentages obtained for ^{131}I (the only radionuclide in which permeation was observed). The values described in this table indicate the dose rate to which the skin of the hands will be exposed as long as the contamination remains on the skin. The 5 minutes latex glove case was considered as generation non-dose rate in skin in order to the uncertainty about the internal contamination compared to the MDA.

Table 14: Estimated dose rate in skin due to contamination of the hands due to permeation in a contamination of the gloves with a drop (0,05 mL) of [^{131}I]sodium iodide solution with a concentration of $\boldsymbol{\phi = 3733\ \mathrm{MBq/mL}}$.

		$\dot{D}(\mu Sv/h)$			
Time after contamination (min)		**2**	**5**	**10**	**15**
Glove type	**Vinyl**	-	-	1.61 ± 0.09	3.3 ± 0.4
	Nitrile	-	-	-	1.00 ± 0.09
	Latex	-	-	1.14 ± 0.06	1.26 ± 0.08

4. CONCLUSION

It was shown that all types of gloves used for handling radionuclides in NMS of HCPA protect the user from contamination with [^{99m}Tc]sodium pertechnetate and [^{18}F]FDG, with no detectable permeation for the manipulation time intervals with the same pair of gloves.

It was also shown that all types of gloves used showed permeation of [^{131}I]sodium iodide for 15 minutes, and no detectable permeation (considering the uncertainties) up to five minutes after contamination. Among the gloves analyzed, nitrile glove presented the greatest radiological protection against contamination from ^{131}I, protecting the user from contamination within 10 minutes of use after external contamination. Furthermore, the nitrile glove allowed for permeation resulting in a radiation dose rate about 3.3 times lower than the vinyl glove and 1.26 lower than latex glove, both for 15 min interval after contamination. Thus, vinyl gloves presented the worst radiological protection for contamination between the tested gloves for ^{131}I between times of 10 and 15 min after contaminations.

Despite this work indicates the detectable permeability of ^{131}I in all gloves tested, the calculated values for hand contamination are very low. This study finds, in the worst case, 6.6 mSv per year (in terms of radioprotection, a value of 2000 hours per year can be considered), which is well below the exposure limit of extremities of 500 mSv per year [3]. Although this kind of contamination is not the only form of extremities exposure in nuclear medicine, the contribution here is very small.

For further studies, could be relevant to evaluate the correlation between the activity deposited in a cotton (used in the wipe test) and in the skin in a real contamination, once the adherence of the permeated material shall not be the same for the cotton and skin.

The investigation carried out was hampered by a crisis in the supply of radioactive material in Brazil during its development [18], which made it impossible to carry out repeat tests for a more accurate statistical analysis. Further studies should be carried out with a larger number of samples.

ACKNOWLEDGMENT

This work was made possible by the fundamental contribution of the members of the HCPA, mainly the NMS staff and the Medical Physicists and Radioprotection Service, for providing the necessary support and resources. Additionally, this investigation received financial support from the Brazilian Unified Health System (Sistema Único de Saúde, SUS), including a Multiprofessional Residency award. Crucial technical contributions and revision were also made by members of the Chemical Institute of the Federal University of Rio Grande do Sul, National Nuclear Energy Commission (CNEN) and Radioprotection and Dosimetry Institute (IRD).

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