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Original article

DETECTION AND DETERMINATION OF RADIOACTIVE SURFACE CONTAMINATION WITH THE USE OF GAMMA CAMERA

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Abstract

Introduction: In the nuclear medicine departments, the risk of radioactive contamination is significantly higher compared to other medical facilities. Although the gamma camera is used to scan patients who have been administered certain amounts of radioactive materials for medical purposes, this paper presents the possibility of using the gamma camera to detect and determine radioactive surface contamination.

Material and methods: For the purposes of this paper, an indirect method was used to determine the surface contamination, by taking wipe tests. These wipe tests were taken from a room where patients who are treated with I-131 therapy stay. The wipes were then measured using Gamma Camera – SoloMobile (DDD-Diagnostic) and an instrument for detection and measurement of radiation from the wipe tests FHZ 732 GM – Pancake (Thermo Electron).

Results and Conclusion: After the readings, the values of surface contamination (S_c) were calculated for both the gamma camera and the standardized instrument for determining surface contamination. After comparing the obtained results, the conclusion is that the gamma camera - SoloMobile can be used to detect surface contamination caused by gamma emitters. Notably, for S_c values greater than $1Bq/cm^2$, satisfactory results were obtained, while for S_c values below $1Bq/cm^2$, significant deviations were observed compared to those obtained with the standard instrument for detection of surface contamination.

Keywords: gamma camera, nuclear medicine, surface contamination, wipe test, I-131

Introduction

Assessment of radioactive surface contamination is an important part of the application of safety standards when workingwith open radioactive sources. Radioactive surface contamination is unwanted radioactive material deposited in an uncontrolled manner in, or on living or non-living objects, in such concentrations as to cause operational inconvenience or radiological hazard. A potential radiological hazard arises from the presence of radioactive surface contamination. It can be airborne and subsequently inhaled, it can be transmitted by hand contact, through food and ingestionand it can penetrate the skin or enter an open wound causing an internal radiological hazard. External contamination occurs when radioactive material deposits on the skin, hair or clothing.

Nuclear medicine is an integral and growing field in the diagnostics and treatment of the diseases. Monitoring the protection of individuals and radiation contamination in the workplace is vital for maintaining safe working environment in nuclear medicine departments. In nuclear medicine facilities there is a risk of contamination with radioactive materials for workers of every profile (hygienists, technicians, doctors, medical physicists...)[1]. Examinations in nuclear medicine involve working with open radioactive sources, which are the main source of radiation exposure. When handling open radioactive sources, there is an increased probability of skin contamination. Contamination can cause an increase in radiation dose, whether external or internal. Internal contamination occurs when the activity is absorbed through the skin and enters the body. External contamination occurs when a component of radioactive material is deposited on the skin or other parts of the body. In addition to possible health problems, it should be noted that radioactive contamination can also affect the quality of patient scans, due to the possible contamination of the imaging equipment or the patient himself.

Radioactive iodine 131(I-131) is used for treatment of thyroid cancer. Patients receiving I-131 must be isolated in secure hospital rooms until radiation levels fall below a specified threshold. The large amount of iodine-131 (I-131) activity excreted by the patient through sweat, saliva, breath, and urine during hospitalization can cause radioactive contamination[2,3].

Contamination can also be classified as: "fixed" and "loose"[4]. "Fixed" is one that is not transferred from a contaminated to an uncontaminated surface upon contact, while "loose" contamination can easily be transferred from a contaminated to an uncontaminated surface.

Material and methods

Contamination monitoring techniques can be divided into “direct" and "indirect" methods[5]. The direct method generally means the use of portable instruments, the so-called contamination monitors for radiation detection and detection of both fixed and loose contamination[6]. When direct methods are inapplicable, primarily due to unfavorable geometry or when it is necessary to determine whether the contamination is "fixed" or not, indirect methods are used, which detect only loose contamination. These include taking samples of the surface contamination, i.e. smears, which are then examined for radioactivity. In many circumstances, the two methods are complementary and both should be used to achieve a complete overview of the condition of the surface being examined.

For the purposes of this paper, an indirect method was used by taking wipe tests. These wipe tests were taken from a room where patients who are treated with radioisotope I-131 reside. Patients treated with I-131 stay in the room for two to three days until the patients' residual activity is low enough to warrant their release from the hospital. Contamination originates primarily from patients' expectoration, secretion, sweating, showering, urination, etc[7]. The radioisotope of Iodine I-131 undergoes beta minus decay,which subsequently leads to the emission of gamma radiation, which through wipes can be detected with the help of a gamma camera. Wipes were taken from five measurement points:1. Power switch - in the room, 2. Corridor, 3. Room floor, 4. Toilet - in front of the sink, 5. Toilet - in front of the shower cabin, at five different time slots (dates). The area from which the wipes were taken is 100 cm^2. Suitable filters are used for taking the wipes, which are additionally soaked with ethanol (C_2H_6O), for better absorption of the potentially contaminated material.

After taking the wipes, they were then measuredwith a gamma camera (without using collimator), which is used for thyroid scanning at the Institute of Pathophysiology and Nuclear Medicine:

- Gamma camera –SoloMobile (DDD-Diagnostic) **(Figure-1)**

Energy range: 55-400 keV
Measuringunit: time or number of counts

Fig. 1. Gamma Camera –SoloMobile

and with an instrument for detection and measurement of radiation intensity Radiameter ESM FH 40 G-L 10 (Thermo Electron), connected to a probe for detection and measurement of radiation from the wipe tests, property of the Institute for Public Health of Republic of North Macedonia:

- Probe – FHZ 732 GM– Pancake(Thermo Electron) **(Figure-2)**

Energy range: 30keV – 4.4 MeV
Measuring unit: counts per unit time, range: 0.1 – $10^4 s^{-1}$

Fig. 2. Probe – FHZ 732 GM–Pancake

The purpose of the measurements was to examine the possibility of introducing a new practice, hitherto unknown, i.e. insufficiently investigated, which will allow the detection and calculation of radioactive surface contamination, using a gamma camera. In doing so, the Institute of Pathophysiology and Nuclear Medicine will receive a new method, which will enable it to improve its radiation protection capacities, in terms of detecting and managing of surface contamination.

Results

Wipe tests were taken from five different positions (point 1-5) in the room where patients treated therapeutically with I-131 stay, on five different dates, in the period from 02.07.2024 to 06.09.2024.

One of the parameters needed to calculatethe surface contamination value from the measured counts is the efficiency of both instruments with which measurements weremade. The efficiency of the instrument depends on several factors: the type and dimension of the detector, which type of radiation is measured (alpha, betaor gamma), scatter radiation, absorption of the radiation by the detector, etc. The efficiency of the instrument can be determined in two ways[5]:

1. Referring to the documentation provided by the manufacturer, for the specific type of radiation
2. By measurement of counts per second (cps) of an appropriatestandard sourceofknown activity, where efficiency is calculated by:

Efficiency = [count rate of the instrument (cps) – background count rate (cps)] / known activity of standard source (Bq)

The efficiency of the instrument FHZ 732 GM – Pancake (Thermo Electron) is given by the manufacturer and it is E=0.30 cps/Bq. For the calculation of the efficiency of the Gamma Camera – SoloMobile (DDD-Diagnostic) the method was used by measuring a source with a known activity. For this purpose, a radioisotope Tc-99m with a known activity was used, which was applied to the same filter with which the wipes were taken. After the readings and the calculation of the efficiency value of the gamma camera, E=0.29 cps/Bq was obtained.

Surface contamination is defined as the ratio of activity per unit area (Bq/cm^2). The numerical value of the surface contamination is determined according to the formula [8]:

$$\mathrm{Sc} = \frac{(N - N_B)}{E * A * F}$$

S_c - surface contamination (Bq/cm^2)

N - measuredcounts per second (cps) of the wipe test

N_B - measured counts per second (cps)without wipe test, i.e. background count rate

E - instrument efficiency (cps/Bq)

A - area from which the wipe test has been taken (cm^2)

F - pick-up factor of the wipe test

The pick-up factor of the wipe test represents the percentage of contamination that is obtained with one wipe from the surface. Traditionally, a value of the pick-up factor of 10%, i.e. F=0.1, is used.

Based on the readings of the wipes and the calculation of the surface contamination values, the following results were obtained, given in the tables (Table 1 to 5), respectively for points 1 to 5.

Table 1. Calculated values for the surface contamination from point-1, obtained by reading with Pancake detector and Gamma camera

Point-1	**Contamination S_c (Bq/cm^2)**	
Date:	**Pancake**	**Gamma**
02.07.	0.60	0.01
07.08.	0.20	0.36
16.08.	0.58	0.83
22.08.	0.84	0.47
06.09.	0.09	0.06

Table 2. Calculated values for surface contamination from point-2, obtained by reading with Pancake detector and Gamma camera

Point-2	**Contamination S_c (Bq/cm^2)**	
Date:	**Pancake**	**Gamma**
02.07.	0.63	0.23
07.08.	0.36	0.28
16.08.	0.58	0.39
22.08.	0.39	0.82
06.09.	19.42	17.49

Table 3. Calculated values for the surface contamination from point-3, obtained by reading with Pancake detector and Gamma camera

Point-3	**Contamination S_c (Bq/cm^2)**	
Date:	**Pancake**	**Gamma**
02.07.	0.52	0.64
07.08.	0.31	0.41
16.08.	2.31	2.24
22.08.	1.45	1.07
06.09.	12.94	14.60

Table 4. Calculated values for the surface contamination from point-4, obtained by reading with Pancake detector and Gamma camera

Point-4	**Contamination S_c (Bq/cm^2)**	
Date:	**Pancake**	**Gamma**
02.07.	0.35	0.11
07.08.	1.62	1.92
16.08.	3.67	4.56
22.08.	3.24	3.30
06.09.	10.90	9.58

Table 5. Calculated values for the surface contamination from point-5, obtained by reading with Pancake detector and Gamma camera

Point-5	**Contamination S_c (Bq/cm^2)**	
Date:	**Pancake**	**Gamma**
02.07.	8.59	6.61
07.08.	3.48	2.43
16.08.	16.57	14.59
22.08.	3.84	3.30
06.09.	10.50	11.13

Discussion and conclusion

According to the guidelines of the International Atomic Energy Agency – IAEA[9] that describe the procedures for assessing surface contamination, the proposed reference levels and response actions are as follows (Table 6):

Table 6. IAEA proposed reference levels

S_c – Surface contamination (β/γ)	Response/Action
S_c< 1Bq/cm^2	- No action required
1Bq/cm^2<S_c< 10Bq/cm^2	- Initiate make safe actions and decontamination, considering eventual need for additional personal protective equipment - Inform room responsible and radiation protection officer (RPO)
S_c> 10Bq/cm^2	- Initiate make safe actions - Inform room responsible and consult with RPO about further actions (decontamination, eventual need for additional personal protective equipment…)

According to the results obtained from the surface contamination calculation, out of a total of 25 wipes taken, 12 of them have surface contamination S_c< 1Bq/cm^2, 8 with 1Bq/cm^2<S_c< 10Bq/cm^2 and 5 with S_c> 10Bq/cm^2.

Based on experimental results it can be said that the area with the highest contamination in the room of patients treated with I-131 radionuclide is the surface of toilet pottery. This fact is in accordance with the studies from other authors, who are dealing with the problem of the surface contamination. Due to the constantly increased level of surface contamination in the toilet, there is a need for more careful and frequent maintenance of toilet hygiene. The general conclusion, from a certain number of studies is that, ventilation of the room, meticulous cleaning of contaminated areas and the sweeping test must be implemented in each room where the patients are treated with radionuclides before the treatment of other patients. Also, the importance of awareness on radiation surface contamination among hospital personnel and patients should be emphasized[10, 11].

The average and standard deviations values of the surface contamination measurements obtained using the gamma camera – SoloMobile, compared to the values obtained using the instrument for detection and measurement of radiation from the wipe tests - FHZ 732 GM – Pancake are given in table-7**.**

From table-7 it can be noted that the deviations of the obtained results, where S_c< 1Bq/cm^2, are quite large, and with an increase in the value of the surface contamination, the percentage of deviation decreases.

Table 7. Deviations of the surface contamination

S_c – Surface contamination	Average deviation (in %)	Standard deviation (in %)
S_c< 1Bq/cm^2	54.29	29.61
1Bq/cm^2<S_c< 10Bq/cm^2	17.64	10.55
S_c> 10Bq/cm^2	10.57	2.77

A general conclusion that can be drawn is that the gamma camera – SoloMobile, which at the Institute of Pathophysiology and Nuclear Medicine is primarily used for thyroid scanning, can be used for detection of surface contamination caused by gamma emitters. The obtained quantitative values for S_c<1Bq/cm^2 (for which according to the IAEA guidelines no action is required) show quite a large deviation in relation to those obtained with a standard instrument for detection of surface contamination. For values of S_c>1Bq/cm^2 obtained through the readings and calculations, the gamma camera gives quite satisfactory results, in relation to the standard instrument for the detection and measurement of surface contamination.

Conflict of interest statement. None declared.

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