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Analysis of Radiation Exposure Level on Linen and Other Objects in Patient Rooms at Nuclear Medicine Installation

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ABSTRACT

Analysis of radiation contamination levels has been carried out using an Atomtex surveymeter in the patient rooms after thyroid cancer ablation therapy, in the Nuclear Medicine Installation, Abdoel Wahab Sjahranie Hospital. This study aims to measure the level of radiation exposure based on the rate of radiation exposure and radiation contamination of objects in the patient rooms after ablation therapy, and to find out how long linen can be washed since the first measurement. Data collection was carried out once a week, on the same weekday, for five weeks for objects in the patient rooms by using the surveymeter at a fixed distances from the objects' surfaces. Radiation contamination measurements for linen items were carried out for 3 d by aiming the surveymeter to container containing linen items from certain distances. Based on this study, the level of radiation exposure obtained is categorized as low because the value range is below 10 μSv/h. The radiation contamination for some objects are categorized as low-level exposure because the value is less than 3.7 Bq/cm^2. Other objects tend to be in the moderate-level category because the value is more than 3.7 Bq/cm^2 and less than 37 Bq/cm^2. The values obtained refer to the standard issued by BATAN. It can be concluded that the patient rooms in the Nuclear Medicine Installation of Abdoel Wahab Sjahranie Hospital are safe.

INTRODUCTION

Radiation protection is a set of practices to protect against harms caused by exposure to radiation, both those that immediately appear and those that may appear in the future. Parts of radiation protection are the measurement of the rate of radiation exposure and detection of radiation contamination on objects which have the potential to be exposed to radioactive substances [1]. In the postablation therapy patient ward for thyroid cancer, the radioactive substance commonly used is iodine-131 (^{131}I). ^{131}I is a radioactive isotope which is routinely administered as sodium iodide-131 (Na^{131}I) by health-care providers to both diagnose and treat thyroid disease [2].

According to [3], In most cases, 50 % to 60 % of the administered activity is excreted in the first 24 h, and around 85 % is excreted over a stay of 4 d to 5 d in hospital. This represents a significant potential for radioactive contamination. Direct contacts between radioactive materials and objects in patient rooms resulted in measurable contamination on those objects, including on linen items. Linen service which does not meet standards, such as by not cleaning the items adequately, will affect the quality of hospital services [4]. This is especially true if the linen items are used in nuclear medicine installations where the linen items must not only do the linen items must be kept hygienic, but they must be further monitored for radioactive substance contamination. For this reason, it is necessary to carry out linen supervision in order to reduce the risk of health and environmental problems [5].

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In nuclear medicine installations, radiation from the linen used by inpatients need to be measured to ensure that there is no radiation contamination or that the contamination level is low enough to allow the linen to be washed, considering that inpatients in nuclear medicine installations have been given radioactive substances as part of the treatment. Linen management which is not in accordance with standards has negative impact on patients and the officers. In facilitating the process of washing linen items, a method which can be used is sorting linen items. The sorting which can be done is to separate contaminated linen items from uncontaminated linen items until the linen items are safe when put together [6].

Measurement of exposure levels and radiation contamination need to be done, due to the unwanted effects of radioactive substances when contacting a healthy body. Ideally, all contamination should be removed; however, there are several considerations to determine hazards for the decontamination process [7]. This study itself aims to determine the level of radiation contamination in the patient rooms after ablation therapy and to monitor until the linen items can be managed by the laundry unit. Ambient radiation monitoring in an ^{131}I isolation room showed that there was negligible risk of harm in terms of the occupational radiation dose level after patients were released [8].

A similar study has been conducted by [9] using a Mini-Con surveymeter. Based on this research, the measured radiation exposure rate is relatively low, namely, below 10 µSv/h. Another study was conducted by [10] regarding the measurement of skyshine radiation exposure in the rooftop area of the Radiotherapy Unit at Pertamina Central Hospital Jakarta. All the results of the final value of radiation exposure obtained were below 1 mSv/y, which means that the roof area of the radiotherapy building can be declared as safe. The dose limit value for the public has been stipulated in the Regulations of the Head of the Nuclear Energy Regulatory Agency (BAPETEN) No. 8 Year 2011 Article 32a and No. 4 Year 2013 Article 23a concerning an effective dose of 1 mSv/y. This dose limit value is set for the safety of the area for people living in the vicinity of the radiation source. Another study was conducted by [11] which was carried out at the Radiology Installation of Padang-area hospitals of Naili Datuak Buang Sakti (DBS) Hospital, Selaguri Hospital, and Andalas University (UNAND) Hospital. Measurements of radiation exposure rate were performed using a Fluke surveymeter. The results of the radiation exposure rate show that the three hospitals were safe. Research conducted by [12] showed mixed behaviours for radioiodine-administered patients. It concluded that 50 % of inpatients were discharged within the first 48 h after radioiodine administration. Another study, conducted by [13], showed that the doses to the family members of ^{131}I therapy outpatients was far below the limit (5 mSv) mandated by current NRC regulations.

In this study, radiation exposure and radiation contamination were measured on objects in the patient rooms after ablation therapy using a surveymeter. In the medical field, this research can be used as a benchmark in handling objects that have the potential to be contaminated by exposure to radioactive substances so that proper handling can be carried out. This research can increase protection for medical personnel from radioactive exposure because it can estimate the dose received by the body through measurement. For now, not many studies have discussed radiation contamination of linen items, even though linen items are an object that has direct contact with patients. Linen is also an object made of cloth, and it is known that the most probable radiation exposure from the patient's body can be in the form of sweat, vomit, urine, and saliva, all of which can be easily absorbed by fabrics including linen.

THEORY

Iodine-131

The radioisotope is an isotope which emits radiation to achieve stability [11]. There are three common kinds of ionizing radiation emitted by radioactive substances, *i.e.*: alpha particle radiation (α), consisting of positively charged particles (helium-4 nuclei); beta particle radiation (β), consisting of negatively charged particles (high-energy electrons); and gamma rays (γ), consisting of high energy photons (electromagnetic waves with a wavelength smaller than the X-ray wavelength) [14]. Figure 1 shows the penetrating power of radioactive rays.

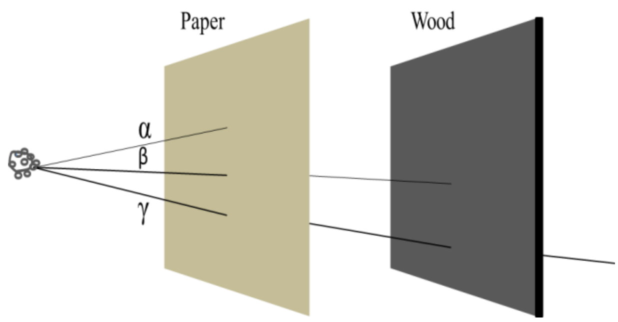

Fig. 1. The penetrating power of radioactive rays [15].

One of the radioisotopes used in nuclear medicine is ^{131}I. ^{131}I is used as a radioactive substance for thyroid cancer therapy because it meets the requirements as a radiopharmaceutical with the resulting emissions in the form of beta and gamma rays and a half-life of 8.05 d [15]. The ^{131}I emits gamma rays with an energy of 364 keV (82 % of all decays) and beta rays with a maximum energy of 606 keV (89 %). Gamma emitters are used for disease detection, while beta emitters are used as cell destroyers with the ability to penetrate tissues with a thickness of 0.8 mm [16]. Hence, higher doses of radioiodine are sometimes less perilous compared to lower doses, since they will, in general, eliminate tissues that would, in one way or another, become malignant owing to radiation [17].

Figure 2 shows the decay scheme of iodine-131. In general, ^{131}I is produced by irradiating natural tellurium targets in research reactors. The isotope tellurium-130 (natural abundance θ = 34 %) will absorb neutrons and is activated to become ^{131}Te which subsequently decays with a half-life $T_{½}$ of 25 min to ^{131}I [19].

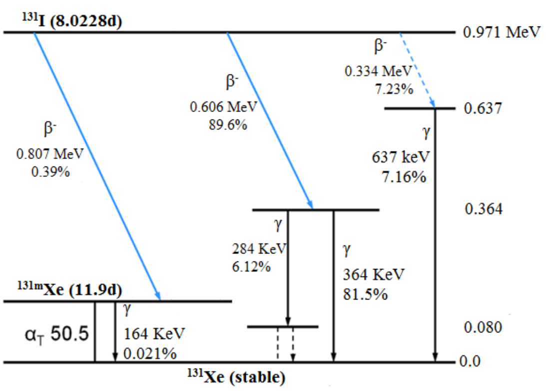

Fig. 2. Decay scheme for ^{131}I [18].

Linen

Linen is a fabric that is used in hospitals for various needs including for covering mattresses and pillows, as blankets, and as clothes for patients [6]. These needs result in linen coming into direct contact with patients. Linen items which have been used need to be managed to prevent disease transmission to patients, staff members, and other linen users. Additionally, for the treatment of patients who use radioactive substances, the linen which has been used must be monitored because the possibility of it being exposed to radioactive substances is very high. Thus, monitoring process is needed until the linen is at the washing stage. The collection process of dirty linen is based on Minister of Health Regulation No. 7 of 2019 that states that sorting linen starts with putting the linen in a container according to its type, labeling it, counting, and recording the amount of linen in the room until the linen is in the washing process [20].

Radiation protection

ALARA (as low as reasonably achievable) is the principle of radiation protection which means that radiation must be kept as low as possible to minimize the risk of cancer and tissue damage [21]. The goal of radiation protection in nuclear medicine is to ensure that the expected medical outcome for the patient is achieved, and procedure optimized while limiting the radiation risk to the patients, medical personnel and public [22]. Table 1 shows dose limits for radiation workers and the public.

Table 1. Limit value dose for radiation workers and the public [23].

Application	Annual Dose (mSv)	
	Radiation Workers	Community
Effective dose	20	1
Equivalent dose for lens of the eye	20	15
Equivalent dose for the skin	500	50
Equivalent dose for hands and feet	500	-

The dose limit values set by BAPETEN are as follows, among others: a. The average effective dose is 20 mSv/y over a period of 5 years, so that the accumulated dose over 5 years may not exceed 100 mSv; b. Effective Dose of 50 mSv in 1 year; c. The equivalent dose for the lens of the eye is an average of 20 mSv/y in a period of 5 years and 50 mSv in any 1 year period; d. The equivalent dose for the skin is 500 mSv/y; e. The equivalent dose for the hands or feet is 500 mSv/y; f. The dose limit value for members of the public follows the pattern of application for radiation workers with a lower value, *i.e.*, 1 mSv in 1 year.

Work area control

Working area usually is divided into controlled and supervised areas. Control of the work area in each area is based on the dose rate, as follows [1]: a. Areas with a dose rate of less than 10 μSv/h. Work areas with a dose rate of less than 10 μSv/h do not require special precautions against external radiation. If someone works in this area, then in a year (2000 working hours) the radiation dose received averages less than 20 mSv/y and in a period of 5 years the accumulated dose does not exceed 100 mSv; b. Areas with a dose rate of greater than 10 μSv/h. Work areas with a dose rate exceeding 10 μSv/h should be marked for radiation. The safety department or radiation protection organization is responsible for routine monitoring and documentation [1].

Work area control must also consider the risk of internal radiation exposure which can enter the body through the digestive tract, inhalation, absorption through the skin, or contamination of wounds. To avoid it or to reduce the risk of exposure when taking measurements, the principles of radiation safety are applied, including reducing radiation exposure time, adjusting the distance from the radiation source, and using equipment for radiation protection.

This principle is applied as an effort to maintain radiation safety for personnel and workplaces [24]. Whether large or small, the dose of radiation received, be it on patients, workers, or the environment, will definitely still have an stochastic effect. For this reason, it is necessary to be careful about the dangers of radiation effects by knowing the safe dose limits and how to minimize radiation exposure [25].

Radiation exposure to workers can be caused by human activities, such as the use of radiation sources and radioactive substances, traveling by air, and the use of X-ray machines in the medical, research, and education fields. To control radiation exposure, measuring devices are needed to monitor existing radiation contamination [26].

Radiation exposure rate

Monitoring of radiation exposure can support the level of work safety in the Nuclear Medicine Installation. The exposure can be calculated using Eq. (1).

$$x_g = \left(x_a - x_{Bg}\right) \times F_K \tag{1}$$

In Eq. (1), x_g is the actual exposure rate at the measured place (μSv/h), x_a is the exposure rate of the measuring instrument (μSv/h), x_{Bg} is the background exposure rate (μSv/h), and F_K is the calibration factor of the measuring instrument [27].

Radiation contamination rate

Radiation contamination is the presence of residual radioactive substances on the surface of an object, where its presence is unwanted or unnecessary. The level of radiation contamination can be calculated by Eq. (2).

$$k_s = \left(k_a - k_{Bg}\right) \times F_K \tag{2}$$

In (2), k_s is the actual contamination at the measured place (Bq/cm^2), k_a is the contamination value read on the measuring instrument (cpm, cps, or Bq), k_{Bg} is the readable background contamination value (cpm, cps, or Bq), and F_K as a measuring instrument calibration factor [28]. Table 2 shows the distribution of contaminated areas.

Table 2. Distribution of contaminated areas.

Contaminated Area	Transmitter β (Bq/cm^2)
Low	$0 < \beta < 3.7$
Medium	$3.7 \le \beta \le 37$
High	≥ 37

Surveymeter

The surveymeter is a measuring instrument that can directly provide information on the rate of radiation dose in an area. The measured value on the surveymeter is the radiation intensity; the intensity value is converted into a dose rate scale electronically. All types of detectors which can give direct results, such as gas-filled, scintillation, and semiconductor detectors, can be used as surveymeters. Due to practical and economic considerations, the Geiger-Müller gas-filled detector is the most widely used. There are many surveymeter types, one of which is the Atomtex AT6130 that is a radiation measuring instrument intended to measure gamma, X-ray, and beta radiation on contaminated surfaces [29].

METHODOLOGY

In this study, the Atomtex AT6130 Sn.21326 Surveymeter measuring beta and gamma rays was used for an energy range of 20 keV to 3 MeV with a calibration factor of 1.02. The Regulation of the Head of the Nuclear Energy Monitoring Agency (BAPETEN) Number 1 Year 2006 requires each radiation protection device to be calibrated periodically by the authorized agency [30]. It aimed to test the accuracy of the displayed value of the instrument against the actual value.

Ideally, the calibration factor is 1. However, since not all measuring instruments have a calibration factor equal to 1, the values ranging from 0.8 to 1.2 are acceptable [31]. The instrument used in this study, an Atomtex AT6130 Sn.21326, was periodically calibrated at BATAN. It used to detect and measure the level of exposure to radiation rate and radiation contamination.

There are five patient rooms which were measured every week. They are occupied by five different patients every week, so the total of patients involved was 25 people for this study. All of these patients were previously administered with ^{131}I radioactive substance at a dose of 100 mCi for treatment based on a doctor's prescription. Measurements in the room were carried out the day after the patient was declared safe to go home. It was done to ensure the room was safe from radiation exposure originating from these patients. Each measurement, both the measurement of dose rate and of radiation contamination, was limited to about 10 s per object with five repetitions in each room being measured. This procedure was meant to ensure that the measurement process would not take too long, *i.e.*, not exceed approximately 67 min.

Measurements were carried out in order to obtain data on the radiation exposure to the object and the radiation contamination of the object. Objects to be measured were mayo stands, tables, clothing boxes, door handles, toilets, sinks, trash cans, and chairs. Measurements of radiation exposure levels were done on every Thursday for 5 weeks. First, background dose exposure levels were measured by pointing the Atomtex surveymeter detector approximately one meter from the opened front door in the patient room to be measured. Background radiation measurements were carried out to find out whether there was radiation exposure in the environment around the room, outside of the source to be measured. Then, the next step was measuring the level of radiation exposure to an object; the measurement was performed from a distance of 30 cm, and it can be performed from any side as long as the side is chosen consistently.

To measure the level of radiation contamination, the cap of the back of the Atomtex surveymeter was opened. This was done because the back side is sensitive enough to be used to measure the flux density of beta particles from contaminated surfaces. In response to opening or closing the back cap, this instrument automatically changes the unit of the displayed quantity; the radiation dose rate is presented in µSv/h, while radiation contamination is presented in Bq/cm^2.

The measurements of radiation contamination on linen items requires a slight adjustment in technique. The linen items measured were from the inpatient rooms at the nuclear medicine installation. Linen is a material that easily absorbs liquids, and the linen items were in direct contact with patients. Those items were exposed to direct contamination through the patients' sweat, saliva, or hairs which were still wet after washing. This allowed for a high degree of contamination. Therefore, the linen items were put into three closed containers which were then measured using surveymeters for 3 d from a distance of 1 m from the container front and from a distance of 30 cm from the top of the closed container. The three closed containers, denoted as Containers 1 through 3, were provided in a separate place outside the patients' room. They were provided specifically to accommodate linen items which had been used in the five rooms. Container 1 was used to store linen items from Room 1 and Room 2, while Container 2 was used to store linen items from Room 3 and Room 4, whereas Container 3 held linen items from Room 5. There is no specific reason for this particular way of combining these linen items; it was done to reduce the use of containers as well as to make measurements easier.

As defined by United States Nuclear Regulatory Commission Part-20 regarding standards for protection against radiation, a radiation area is an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 h at 30 cm from the radiation source or from any surface that the radiation penetrates. A very high radiation area means an area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving an absorbed dose in excess of 500 rads (5 Gy) in 1 h at 1 m from a radiation source or 1 m from any surface that the radiation penetrates [32]. If the distance was too close, it could make the measuring instrument sensitive which affected its accuracy in measurement. Linen items are considered safe for laundry if the value of the radiation exposure rate from them is close to the background values.

RESULTS AND DISCUSSION

Figure 3 shows comparison of radiation exposure values from the first week to the fifth week which has been averaged, between objects in Room 1, Room 2, Room 3, Room 4, and Room 5 which have been measured. Figure 4 shows comparison of radiation contamination values between objects from the first week to the fifth week in Room 1 to Room 5. Figure 5 shows a graph of the average exposure rate from linen items as measured from the front direction closed container from a distance of approximately 1 m. Figure 6 shows a graph of the average exposure rate from linen as measured from above closed container from a distance of approximately 30 cm.

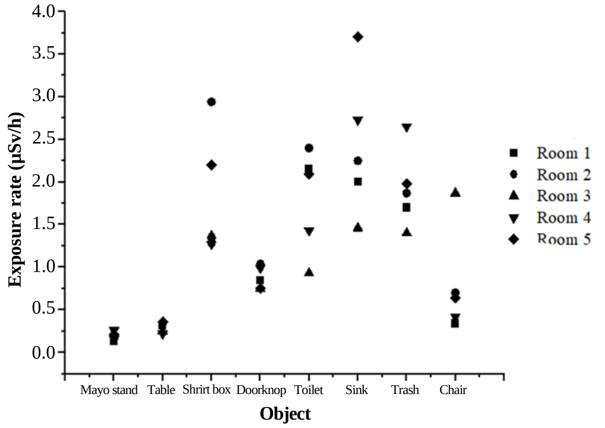

Fig. 3. Average radiation exposure rate for various linen items.

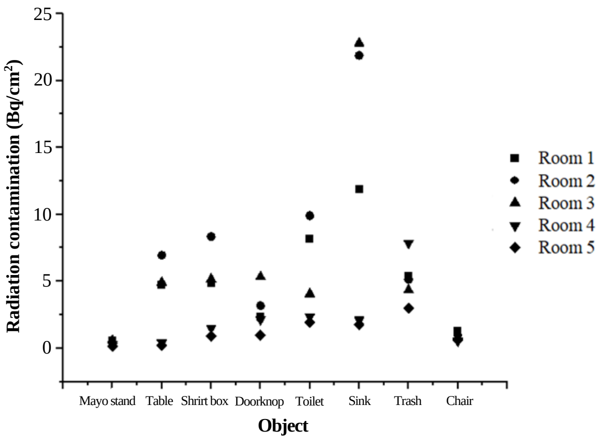

Fig. 4. Average radiation contamination for various linen items.

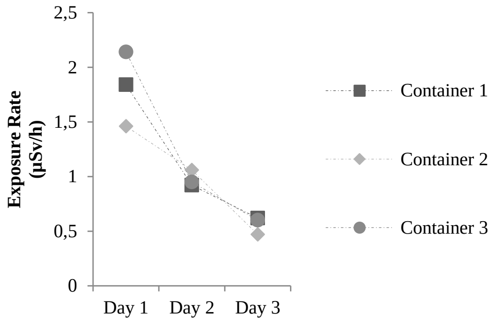

Fig. 5. Graph of average exposure rate from linen containers from front with a distance of 1 m.

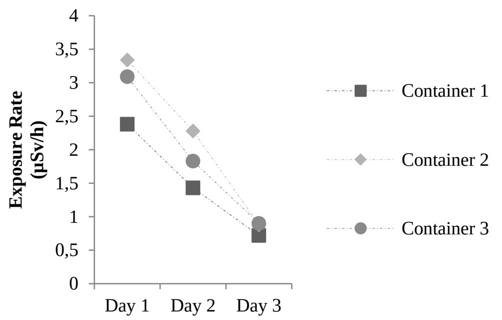

Fig. 6. Graph of average exposure rate from linen containers from above with a distance of 30 cm.

From the graphs, it can be seen that the highest average radiation exposure rate value occurs in the sink. It is because the patient performs several activities at the sink such as vomiting, brushing teeth, and washing hands, causing the radioactive substances in the body to also be carried away through either saliva or sweat. The values of radiation exposure obtained vary from time to time, as they are influenced by the activity of each patient. In the 5 weeks and from Room 1 to Room 5, the average radiation exposure rate value was obtained from 25 different patients. The more the activity of the radioactive substances on the object, the higher the degree of exposure. The range of values obtained is from 0.13 μSv/h to 3.7 μSv/h. The value of the exposure level obtained is classified as low level because the dose exposure rate is less than 10 μSv/h. This is in accordance with BATAN's standards regarding control of work areas [33]. Similar research conducted by [28] also obtained a relatively low value and used the same reference from BATAN. Unlike the researchers in [28] who took measurements in the rooms in the nuclear medicine installation, this study focused on the rooms occupied by thyroid cancer patients after ablation therapy.

From Fig. 4, it can be seen that in Room 2 the radiation contamination value is consistently higher than in the other rooms and not much different from the measurement result of the radiation exposure rate in the most highly contaminated spot, namely the sink. This can be caused by the condition of each patient who has occupied the room, including patients who sweat easily, sneeze, or cough, contaminating objects that have been exposed to the liquid. The range of radiation contamination values obtained is 0.15 Bq/cm^2 to 22.8 Bq/cm^2. The contamination value obtained for the mayo stand and chair belongs to the category of low contamination level because the value is less than 3.7 Bq/cm^2, while for other objects such as tables, cloth boxes, doorknobs, toilets, sinks, and trash cans, they are classified as a medium contamination level because the values are more than 3.7 Bq/cm^2 and less than 37 Bq/cm^2.

From Fig. 5, it can be seen that the exposure rate values of Container 1, Container 2, dan Container 3 have decreased from the previous day. The range of average values is 0.47 μSv/h to 2.14 μSv/h. Container 3 has a higher exposure rate of 2.14 μSv/h. Based on it, the values obtained are classified as low level because they are less than 10 μSv/h. They also proved to be in accordance with the chart of radioactive decay and the results were in agreement with the ^{131}I decay time, *i.e.*, 8.1 days.

Based on Fig. 6, it shows that the exposure rate of Container 1, Container 2, and Container 3 have decreased from the previous day. The range of average values is 0.72 μSv/h to 3.34 μSv/h. Container 2 has a higher exposure rate of 3.34 μSv/h. The values obtained are also classified as low level because the dose exposure rates are less than 10 μSv/h.

A similar study has been conducted by the authors of [28]; they showed radiation contamination values with a range of 3.62 Bq/cm^2 to 243 Bq/cm^2, and values for radiation exposure rates range from 0.5361 μSv/h to 1.693 μSv/h in the hot lab room. The study carried out measurements in several rooms in the Nuclear Medicine Installation, but the Hot Lab room was the room that had many objects in it, such as a table, the floor near the table, room floor, trolley, and sink. If we compare the results of measurements taken there to the ones taken in the patients' room which also has many objects, lower values were obtained for exposure to radiation contamination, which is 0.15 Bq/cm^2 to 22.8 Bq/cm^2. Compared with the value of the rate of radiation exposure carried out by [28], the values obtained in this study are higher with a value ranging from 0.13 μSv/h to 3.7 μSv/h. This is because the object being measured and the measuring distance are different.

So far this study has been conducted, the authors have not found references that measure radiation exposure in the patients' room after ablation therapy.

CONCLUSION

Based on the conducted research, the measured radiation exposure rate at the Nuclear Medicine Installation of Abdoel Wahab Sjahranie Hospital showed that the level of radiation exposure in the patient's room after ablation therapy ranges from 0.13 μSv/h to 3.7 μSv/h. These levels of radiation exposure obtained are categorized as low because the range is below 10 μSv/hour. For the measurement of radiation contamination, the range of values obtained is from 0.15 Bq/cm2 to 22.8 Bq/cm2. The contamination values obtained from this range for several objects are classified as low exposure levels because the value is less than 3.7 Bq/cm2, whereas other objects are categorized as medium exposure because the value is more than 3.7 Bq/cm2 but less than 37 Bq/cm2. The values obtained from these measurements refer to the standard values issued by BATAN. It can be concluded that patients' rooms in the Nuclear Medicine Installation of Abdoel Wahab Sjahranie Hospital are safe from radiation exposure.

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AUTHOR CONTRIBUTION

Anisa Putri, Retno Zurma, Rahmawati Munir, and Erlinda Ratnasari Putri equally contributed as the main contributors of this paper. All authors read and approved the final version of the paper.

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