Original Research Article

Analysis of Radiation Dose Acceptance of Radiation Workers at the Radiology Installation of Bali Mandara Hospital

ABSTRACT

Aims: To determine the dose of radiation received by radiation workers at the Radiology Installation of Bali Mandara Hospital based on differences in work professions, Knowing the suitability of the amount of radiation dose received by radiation workers is still within the limits determined by BAPETEN and to find out the difference in receiving external radiation doses to the radiation worker profession at Bali Mandara Hospital.

Place and Duration of Study: Hospital Radiology Installation in Bali Mandara, between August 2022 and October 2022.

Methodology: Using quartile value determination and statistical tests, namely the one sample t-test and manova test.

Results: The data used is radiation dose data that has been measured/read by Surabaya Health Facilities Security Center in the 2018-2021 period. First quartile value (Q_1), second quartile (Q_2) and third quartile (Q_3) for the profession of Doctor Sp.Rad. of 0.149 mSv, 0.191 mSv and 0.211 mSv, Radiographer profession of 0.169 mSv, 0.184 mSv and 0.198 mSv, Nursing profession of 0.167 mSv, 0.185 mSv and 0.195 mSv, Medical Physicist profession of 0.148 mSv, 0.185 mSv and 0.196 mSv and Administrative Personnel profession of 0.091 mSv, 0.181 mSv and 0.209 mSv. From the results of the statistical test, namely the t-test, decision-making was obtained, namely there was no difference between the radiation dose received by radiation workers and the NBD that had been determined by BAPETEN.

Conclusion: In this study, it was known that the radiation dose received by radiation workers based on professional differences was still within the dose limit value set by BAPETEN.

Keywords: Radiation Dose; Thermoluminisence Dosemeter (TLD); Dose Limit Value (DLV), Profession Radiation Worker, Quartile.

1. Introduction

The use of radiation to meet human needs has developed in various aspects of life, it can be seen that radiation is used in the health sector to perform radiological imaging. Radiation entering the human body can cause effects on the radiation worker, from the mildest to the most dangerous. The amount of radiation effect depends on several factors, specifically the kind of radiation, the duration of irradiation, the distance between the radiation source and the body and the presence or absence of shielding among the radiation source and the radiation employee. One way to reduce the occurrence of negative effects due to radiation exposure is to monitor the radiation dose, both external and internal radiation dose measurements. This is so that the dose received by the public and radiation workers does not exceed the set dose limit value.

Based on the Regulation of the Nuclear Power Supervisory Agency (BAPETEN) Number 3 of 2013, Radiation protection is the measures taken to protect patients, workers, members of the

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public and the environment from radiation hazards. Radiation protection carried out to reduce the damaging influence of radiation due to radiation exposure, becomes a must to realize radiation safety. The dose limit value for an average radiation worker should not exceed 20 mSv (millisievert)/year for 5 consecutive years Monitoring of the radiation dose received by radiation workers is carried out using a *Thermoluminisence Dosemeter* (TLD) and a calibrated direct reading dosimeter.

1.1 Radiation

Radiation is the emission of energy through matter or space in the form of heat, particles, or electromagnetic waves or light (photons) from a radiation source. [2]. Radiation in the form of electromagnetic waves is a type of radiation that has no mass and no electric charge. Examples are gamma rays and X-rays and include radiation such as light rays, sunlight, *microwave* waves, radar and *mobile phones* [3]. In general, radiation is divided into two, namely ionizing radiation and non-ionizing radiation.

1.1.1 Ionizing Radiation

Ionizing radiation is a type of radiation that can cause ionization processes when interacting with matter. Types of ionizing radiation include alpha particles, beta particles, gamma rays, X-rays and neutrons. Ionizing radiation can cause death or abnormalities in cells, temporarily or permanently. Ionizing radiation can also cause mutations in genes, thereby inhibiting offspring. However, this ionizing radiation can be used in various medical procedures. The branches of medicine that use ionizing radiation in medical measures are radiotherapy, radiology therapy or radiation oncology [4].

1.1.2 Non-ionizing Radiation

Non-ionizing radiation is a sort of radiation that cannot cause ionization outcomes while interacting with rely [3]. Non-ionizing radiation can be determined in the surroundings of dwelling things. protected in the sorts of non-ionizing radiation consist of radio waves (thru radio and television), microwaves (that are used in cellular telephone transmission), infrared rays (affords electricity in the shape of heat)), and visible mild (daylight). unlike ionizing radiation, non-ionizing radiation isn't always capable of transferring electrons or ionizing atoms, so this radiation is not as dangerous as ionizing radiation. This radiation also has a decrease frequency than ionizing radiation, so the possibility of damage to health could be very smal [4].

1.2 Individual Radiation Dose Measuring Instruments

Individual radiation dose measuring instruments or dosimeters are used to "noted" the dose of radiation that has hit it accumulated over a period of time. The radiation dose measuring instruments received in the health sector include:

1.2.1 Film Dosimeter

A film dosimeter is a radiation dose measuring device consisting of cellulose acetate coated with radiation sensitive material on both surfaces. This radiation-sensitive layer is called an emulsion consisting of gelatine and photosensitive (light-sensitive) components in the form of silver bromide (AgBr) crystals evenly dispersed in gelatine [9].

Film dosimeter offers a fast and convenient method of obtaining a two-dimensional dose distribution by which the cross-section of the film can also provide isodose curve information. This type of dosimeter can also be used to measure the distribution of electron beam doses. The energy dependence of this type of dosimeter can be explained through the fact of the ratio of the collision of the energy stopper in solution and in water that varies with the energy of the electrons [9].

1.2.2 Pocket Dosimeter

Pocket dosimeter is widely used as one of the personal radiation protection tools because it can be read directly and does not require other tools. Pocket dosimeters can be divided into two, namely analog and digital pocket dosimeters. The detector pocket dosimeter used is a gas fill detector with a type of ionization chamber detector (gas fill detector that works in the ionization chamber area). Gas-filled detector consists of two positive electrodes called anodes and a negative electrode called a cathode. This cylindrical detector has its axis serves as an anode and the wall serves as a cathode. The anode will be connected at the positive electric pole and the cathode at the negative pole [8].

1.2.3 *Themolumiescence Dosimeter* (TLD)

Thermoluminescence Dosimeter is a type of personal dosimeter used to measure doses of gamma, X-ray, and beta radiation, as well as neutrons. These TLD use thermoluminescence

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inorganic crystals, such as LiF and CaSO4 materials. This dosimeter is used for a certain period of time, for example one month, which is then processed to find out the amount of radiation dose that has been received [7].

1.3 Radiation Worker

Radiation Worker is any person working in a nuclear installation or ionizing radiation agency who receives an annual radiation dose exceeding the radiation dose for the general public [5]. The ones that include radiation workers, namely radiology specialists, radiographers, nurses who work in radiology and radiotherapy services, radiology administration personnel, medical physicists, etc.

1.4 Radiation Protection

Radiation Protection is a measure taken to reduce the damaging influence of radiation due to radiation exposure [5]. Based on the Regulation of the Nuclear Power Supervisory Agency Number 4 of 2020, radiation protection has 3 (three) basic principles, which are as below:

a. Justification, the use of radioactive substances or other radiation sources should be based on the consideration that the benefits obtained far exceed the risk of radiation harm posed.
b. Optimization of radiation protection and safety must seek to optimize radiation exposure of radiation workers, patients and the public as low as possible in order to achieve diagnostic goals.
c. Dose limitations, the radiation dose obtained by radiation workers and the general public must not exceed the dose limit set by BAPETEN.

1.5 Dose Limit Value (DLV)

Dose Limit Value (DLV) is the largest dose permitted by the Supervisory Agency that can be received by radiation workers and the public within a certain period of time without causing somatic and genetic effects resulting from the utilization of nuclear power [5].

Dose Limit Value that has been set by BAPETEN for irradiation of the whole body or part of the body for radiation workers, which are:

a. The average Effective Dose is 20 mSv/year for a period of 5 (five) years, so that the Dose accumulated in 5 (five) years does not exceed 100 mSv.
b. Effective Dose of 50 mSv for 1 (one) specific year;
c. Equivalent dose for lenses averages 20 mSv/year over a period of 5 (five) years and 50 mSv in a given 1 (one) year;
d. The equivalent dose for the skin is 500 mSv/year; and
e. Equivalent dose for hands and feet of 500 mSv (five millisieverts)/year.

2. METHOD

2.1 Place and Duration of Study

The study was conducted from August to October 2022 at the Radiology Installation of Bali Mandara Hospital.

2.2 Data Processing

Data processing using a conservative approach is the determination of the quartile value of the distribution of radiation dose data workers. The Data were grouped by profession category Doctor Sp.Rad. Radiographers, medical physicists, nurses and administrative personnel. The radiation dose data used is radiation dose data in 2018-2021. The radiation dose data that has been obtained is then processed in the form of determining the quartile value of the dose distribution received by radiation workers [6]. to determine the position Q_1 , Q_2 and Q_3 using Equation 1 as follows:

$$n_{Qi} = \frac{i(n+1)}{4} \tag{1}$$

Where n is the sum of the data and i is the i-th quartile. Furthermore, the quartile values are obtained through Equations 2, 3 and 4 as follows.

$$Q_1 = X_{a,1} + \frac{3}{4}(X_{b,1} - X_{a,1}) \tag{2}$$

$$Q_2 = X_{a,2} + \frac{2}{4}(X_{b,2} - X_{a,2}) \tag{3}$$

$$Q_3 = X_{a,3} + \frac{1}{4}(X_{b,3} - X_{a,3}) \tag{4}$$

Where:

Q_1 : the first quartile value

Q_2 : the second quartile value

Q_3 : the third quartile value

$X_{a,1}$: value before the 1st quartile position

$X_{b,1}$: value after the 1st quartile position

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$X_{a,2}$: value before the 2nd quartile position

$X_{b,2}$: value after the 2nd quartile position

$X_{a,3}$: value before the 3rd quartile position

$X_{b,3}$: value after the 3rd quartile position

2.3 Data Analysis

The statistical test used to analyze the data in this study was a one-sample t-test and a manova test using SPSS software version 25. The test was conducted with a 99% confidence level or a significance level of 0.01. The t-test of one sample was carried out to determine the difference in the receipt of the radiation dose received by the radiation worker which was measured to be the same or not with the limit value of the radiation worker dose that had been set by BAPETEN. The following is a statistical hypothesis of a one-sample t-test:

$H_{0:}\ \mu = \mu_0$ $\qquad$ $H_{1:}\ \mu \neq \mu_0$

Where: $\mu =$ Measurement result data
$\mu_0 =$ Values that have been set by BAPETEN

The hypotheses proposed are:

Profession	Dose (mSv)		
	Q_1	Q_2	Q_3
Doctor Sp.Rad.	0,149	0,191	0,211
Radiographer	0,169	0,184	0,198
Nurse	0,167	0,185	0,195
Medical Physicists	0,148	0,185	0,196
Administrative Personnel	0,091	0,181	0,209

H_0: There is no difference between the radiation dose received by radiation workers as a result of measurements and the radiation dose received by radiation workers that has been determined by BAPETEN.

H_1: There is a difference between the radiation dose received by radiation workers as a result of measurements and the radiation dose received by radiation workers that has been determined by BAPETEN.

From the results of statistical tests will be seen and compared t_{tabel} velue and t_{hitung} velue obtained. If the value of $t_{hitung} < t_{tabel}$ then the hypothesis H_0 accepted and H_1 rejected. Otherwise, if the value of $t_{hitung} >$ t_{tabel} then the hypothesis H_0 rejected and H_1 accepted [10]. Furthermore, to determine the difference in receiving radiation doses in the radiation worker profession, a manova test was conducted with an α = 0.01.

The hypotheses proposed are:

H_0: There is no difference in the acceptance of radiation doses to the radiation worker profession.

H_1: There are differences in the acceptance of radiation doses to the radiation worker profession.

From the results of the manova test, it will be seen and compared the α (alpha) and the value of hoteling trace sig obtained. If the value of hoteling trace sig <α then the hypothesis H0 is rejected and H1 is accepted, otherwise if the value of hoteling trace sig>α then the hypothesis H_0 is accepted and H_1 is rejected.

3. RESULTS AND DISCUSSION

In this study, radiation dose data was grouped based on the category of working professions, such as Doctor Sp. Rad., Radiographers, nurses, medical physicists and administrative personnel. The radiation dose is measured using a Thermoluminisence Dosemeter which the measurement results are then sent to the Surabaya Health Facility Safety Center to read the radiation dose. Calculation result of 1st quartile value (Q_1), 2nd quartile (Q_2) and the 3rd quartile (Q_3) for each of the radiation work professions can be viewed in Table 1.

Table 1 Radiation doses on Q_1, Q_2 and Q_3

The radiation dose that has been measured/read, then the calculation is carried out to determine the value of the first quartile (Q_1), second quartile (Q_2) and third quartile (Q_3) from the distribution of radiation dose data received by radiation workers at the Radiology Installation of Bali Mandara Hospital. Quartile value calculation using Equations 1-3. According to Table 1, the calculation results of the quartile values obtained are profession values obtained are the profession of Doctor Sp.Rad. of 0.149 mSv, 0.191 mSv and 0.211 mSv, the Radiographer profession of 0.169 mSv, 0.184 mSv and 0.198 mSv, the Nursing profession of 0.167 mSv, 0.185 mSv and 0.195 mSv, the Medical Physicist profession of 0.148 mSv, 0.185 mSv and 0.196 mSv and the

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Administrative Personnel profession of 0.091 mSv, 0.181 mSv and 0.209 mSv.

Before conducting a one-sample t-test, a normality test is first carried out which aims to determine whether the data is normally distributed. The normality test used is the Kolmogorov-Smirnov test. Where the data is said to be normally distributed if the kolmogorov-smirnov sig value is greater than 0.01. The kolmogorov-smirnov test results can be viewed in Table 2.

Table 2 Results of normality test

Tests of Normality

	Kolmogorov-Smirnov[a]		
	Statistic	Df	Sig.
Doctor	.158	16	.200
Radiographer	.170	16	.200
Administration	.203	16	.077
Nurse	.243	16	.012
Physicist	.203	16	.077

Based on Table 2, it can be seen that the data for Doctor Sp. Rad., Radiographer, Nurse, Medical Physicist and Administrative Personnel can be said to be normally distributed, It can be seen that the value of *the kolmogorov-smirnov* sig for each work profession is greater than 0.01. Furthermore, a one-sample t-test was conducted on each profession to see if there was a difference in the radiation dose received by radiation workers with the assistance set by BAPETEN. The results of the one-sample t-test can be viewed in Table 3.

Table 3 T_{hitung} Value of one sample t-test in each profession.

Radiation Workers	t_{hitung} Value
Doctor Sp. Rad.	-1386,808
Radiographer	-2586,717
Nurse	-987,458
Medical Physicists	-981,979
Administrative Personnel	-715,021

Based on Table 3, a one-sample t-test was conducted on each profession to determine whether the amount of radiation dose received by radiation workers was still within the limits set by BAPETEN. The results obtained for each profession of Doctor Sp.Rad., Radiographer, Nurse, Medical Physicist and Administrative Personnel are valued at -1386.808, -2586.717, -1074.628, -981.979 and -715.021 and the t_{tabel} value for the five radiation worker professions is 2.60248. From the t-test results, thet_{tabel} value and t_{hitung} value obtained will be compared. Comparison of the t_{tabel} value and the t_{hitung} value can be viewed in Table 4.

Table 4 Comparison of value t_{tabel} and t_{hitung}

Pekerja Radiasi	$t_{hitung} < t_{tabel}$
Doctor Sp. Rad.	(-1386,808 < 2,60248)
Radiographer	(2586,717 <2,60248)
Nurse	(-1074,628 < 2,60248)
Medical Physicists	(-981,979 < 2,60248)
Administrative Personnel	(-715,021 < 2,60248)

Based on Table 4, it is known that t_{hitung} value is smaller than the t_{tabel} value so that H_0 is accepted and H_1 is rejected. Then the decision was obtained that there was no difference between the dose of radiation received by radiation workers and the dose limit value set by BAPETEN number 3 of 2013. Furthermore, a manova test was conducted to see the difference in radiation dose acceptance to the work profession. The outcomes of the manova test can be viewed in Table 5.

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Table 5 Results of manova test

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.988	132.983[b]	5.000	8.000	.000
	Wilks' Lambda	.012	132.983[b]	5.000	8.000	.000
	Hotelling's Trace	83.115	132.983[b]	5.000	8.000	.000
	Roy's Largest Root	83.115	132.983[b]	5.000	8.000	.000
Year	Pillai's Trace	1.163	1.266	15.000	30.000	.282
	Wilks' Lambda	.130	1.640	15.000	22.486	.140
	Hotelling's Trace	4.491	1.996	15.000	20.000	.075
	Roy's Largest Root	3.949	7.898[c]	5.000	10.000	.003

Based on Table 5, a manova test has been conducted to see the difference in radiation dose acceptance for radiation workers in the radiology installation at Bali Mandara Hospital. The result obtained is hoteling trace sig = 0.075, where the value of α = 0.01 so that the hoteling trace sig > α (0.075 > 0.01) then H_0 is accepted and H_1 is rejected. Based on the hypothesis that has been done, it can be concluded that there are differences in radiation doses received by radiation workers. This is because each profession has different tasks in relation to radiation sources, so that it will affect the amount of dose acquisition of each profession.

3 CONCLUSION

The conclusion obtained is:

1. Radiation dose in the first quartile (Q_1), second quartile (Q_2) and third quartile (Q_3) are for the profession of Doctor Sp.Rad. profession by 0.149 mSv, 0.191 mSv and 0.211 mSv, Radiographer profession by 0.169 mSv, 0.184 mSv and 0.198 mSv, Nurse profession by 0.167 mSv, 0.185 mSv and 0.195 mSv, Medical Physicist profession by 0.148 mSv, 0.185 mSv and 0.196 mSv and Administrative Personnel profession by 0.091 mSv, 0.181 mSv and 0.209 mSv.
2. Radiation Specialists, Radiographers, Nurses, Medical Physicists and Administrative Personnel are valued at -1386.808, -2586.717, -1074.628, -981.979 and -715.021 with a t_{tabel} value for the five radiation worker professions of 2.60248. Based on these results, it is known that the value of t_{hitung} is smaller than the value of t_{tabel} so that H_0 is accepted and H_1 is rejected. Then a decision is obtained that there is no difference between the radiation dose received by radiation workers and the dose limit value set by BAPETEN.
3. The results obtained are hoteling trace sig = 0.075, where the value of α = 0.01 so that hoteling trace sig > α (0.075 > 0.01) then H0 is accepted and H1 is rejected. Based on the hypothesis that has been done, it can be concluded that there are differences in radiation doses received by radiation workers.

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