# BATAN PERSONAL DOSE EQUIVALENT $H_p$ (10) AND $H_p$ (3) INTERCOMPARISON RESULTS AT 2018 & 2019

***Hasil Interkomparasi Dosis Ekivalen Perorangan $H_p$ (10) dan $H_p$ (3) Tahun 2018 & 2019 oleh Batan***

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***Abstract***

One of the methods to ensure the quality of a laboratory is participating in an intercomparison activity. For the dosimetry laboratory network in Indonesia, the intercomparison activity is managed by the Secondary Standard Dosimetry Laboratory (SSDL) Jakarta. This paper describes the intercomparison among processing laboratory for personal dose equivalent $H_p(10)$ and $H_p(3)$ using thermoluminescent dosimeter (TLD)/films in 2018 & 2019. The SSDL Jakarta irradiated packages of participant's TLDs/films with Cs-137 and X-rays at a specific equivalent dose. The irradiated dosimeters were sent back to the participants by mail, and then the result was sent to the SSDL Jakarta for evaluation. The evaluation was carried out using the trumpet curve under the International Atomic Energy Agency (IAEA) publication. The results obtained for the 2018 intercomparison show the success rates of 98%, and 2% were outside the acceptable range, whereas for the 2019 Intercomparison, the success rates were 96% and 4% outside the acceptable range. The potential failure of reading the dose value was in the film dosimeter/badge. For those recent two years of intercomparison activities, the success rate was more than 95%. This result of the intercomparison activity showed the excellent quality of the personal dose equivalent $H_p(10)$ and $H_p(3)$ measurement in Indonesia.

**Keywords**: intercomparison, personal dose equivalent, $H_p(10)$, $H_p(3)$, TLD/Film dosemeter

***Abstrak***

*Salah satu metode yang digunakan untuk menjamin kualitas dari sebuah laboratorium adalah dengan berpartisipasi pada kegiatan interkomparasi Untuk jaringan laboratorium dosimetri di Indonesia, kegiatan interkomparasi diselenggarakan oleh Laboratorium Dosimetri Standar Sekunder (LDSS) Jakarta. Makalah ini menguraikan mengenai kegiatan interkomparasi antar laboratorium pemroses dosis ekivalen perorangan besaran $H_p(10)$ dan $H_p(3)$ menggunakan TLD/film tahun 2018 & 2019. LDSS Jakarta melakukan penyinaran terhadap paket dosimeter TLD/film milik peserta dengan berkas radiasi Cs-137 dan sinar-X dengan dosis tertentu. Dosimeter TLD/Film yang telah disinari dikirim kembali ke laboratorium peserta untuk dibaca. Hasil bacaan kemudian dikirim ke LDSS untuk dievaluasi. Evaluasi hasil bacaan dilakukan menggunakan kurva terompet sesuai dengan publikasi International Atomic Energy Agency (IAEA). Hasil yang diperoleh untuk interkomparasi tahun 2018 menunjukkan bahwa tingkat keberhasilan sebesar 98% dan 2% di luar batas nilai dosis yang diperbolehkan, sedangkan untuk Interkomparasi tahun 2019 tingkat keberhasilan sebesar 96% dan 4% di luar batas nilai dosis yang diperbolehkan. Potensi kegagalan pembacaan nilai dosis terdapat pada dosimeter film/badge. Hasil kegiatan interkomparasi ini* menunjukkan kualitas yang bagus untuk pengukuran dosis ekivalen perorangan Hp(10) and Hp(3) di Indonesia.

***Kata Kunci:** intercomparison, personal dose equivalent, $H_p(10)$, $H_p(3)$. TLD/film dosemeter*

## 1. INTRODUCTION

Until 2018, the number of radiation workers in Indonesia reaches around 30,000 radiation workers. It will increase the use of nuclear technology in the community. Every radiation worker must wear a radiation protection device in the form of a passive or active individual dosimeter. The personal dosimeters will be evaluated by the dosimetry laboratory to obtain an equivalent dose.

In 2018 nine dosimetry laboratories in Indonesia had been appointed by the Nuclear Energy Regulatory Agency (BAPETEN). The dosimetry laboratory is a laboratory that carries out individual dose monitoring evaluation services. The dosimetry laboratory has carried out services to evaluate personal dosimetry devices for government and private agencies in recent years.

Based on the regulation (No. 11, 2015) from Head of BAPETEN, to ensure the quality of its evaluation results from a dosimetry laboratory, each dosimetry laboratory is mandatory to participate in intercomparison organized by Secondary Standard Dosimetry Laboratories (SSDL), in this case, Center for Radiation Safety Technology and Metrology (PTKMR) – National Nuclear Energy Agency of Indonesia (BATAN). The purpose of the intercomparison activity is to assess each laboratory (Adjei et al., 2017; Arib et al., 2014). Besides, it will show how far the difference in dose evaluation results between dosimetry laboratories.

Intercomparison activities were also carried out by dosimetry laboratories outside Indonesia, namely in a country or regional scope. The aim is also to ensure the ability and evaluation method used following the applicable protocol. There were examples, such as in Africa (Arib et al., 2014; Msimang et al., 2011), Argentina (Gregori et al., 2007), and Latin America (Saraví et al., 2007).

As SSDL in Indonesia, PTKMR-BATAN was responsible for becoming the technical coordinator of the implementation of intercomparison activities between dosimetry laboratories in Indonesia since 2006. Intercomparison was done by evaluation of the measurement of the equivalent dose Hp(10) and the dose of the Hp(3) eye lens using the TLD/Film badge. The radiation source used is the X-ray beam and the Cs-137 source.

This paper describes the intercomparison activities between dosimetry laboratories in Indonesia in 2018 - 2019. Nine dosimetry laboratories followed the intercomparison program. This paper also discusses the analytical statistic from a few years before in the same intercomparison program.

## 2. BASIC THEORY

### 2.1 Intercomparison Activity

As a participant, the dosimetry laboratory sent a package of thermoluminescent dosemeter (TLD)/film badges to SSDL Jakarta. The TLD/film will be irradiated with an X-ray beam Narrow-80 (N-80) beam quality and Cs-137 beam. After the TLD/film was irradiated, the dosimeter will be sent back to the participant. Then, SSDL Jakarta will evaluate the result from each laboratory after completion. The packages sent to SSDL Jakarta usually consist of TLD/film samples and TLD/film control.

In the 2018 intercomparison activity, there were two types of tests. It was consist of a performance test (stated dose) and a blind test (unstated dose). For the performance test, the participant will evaluate the irradiated dosemeter for a specific dose given by the SSDL Jakarta, which has been stated before. So, the participant has known the actual dose, and then the participant can do the verification of their evaluation result against the actual dose value.

In contrast, for the blind test, the SSDL Jakarta has not given the actual dose value. The SSDL Jakarta only gives the irradiated dosemeter package without informing the actual dose value. The participant should evaluate and inform their result. The dose value will keep classified until all the intercomparison has been complete. In the 2019 intercomparison activity, there was no performance test. It was just a blind test for all participants.

Table 1 Intercomparison Test.

| Year of activity | Beam | Stated Dose (Performance Test) | | Unstated Dose (Blind Test) | |
|---|---|---|---|---|---|
| | | $H_p(10)$ | $H_p(3)$ | $H_p(10)$ | $H_p(3)$ |
| 2018 | X-Ray | √ | - | √ | √ |
| | Cs-137 | - | - | √ | - |
| 2019 | X-Ray | - | - | √ | √ |
| | Cs-137 | - | - | √ | - |

### 2.2 Trumpet Curve Evaluation

Based on the recommendation from the International Commission on Radiological Protection (ICRP) number 60, evaluations were calculated based on the trumpet curve. The trumpet curve is a graphical representation of the acceptable limit in the personal dose equivalent measurement. The normalization value used for the trumpet curve can be determined using Equation 1 below.

$$Q_m = Dose_{participant} \,/\, Dose_{SSDL} \qquad (1)$$

with:

| | | |
|---|---|---|
| $Q_m$ | : | Deviation |
| $Dosis_{participant}$ | : | Evaluation value from participant laboratory |
| $Dosis_{SSDL}$ | : | The dose is given by SSDL |

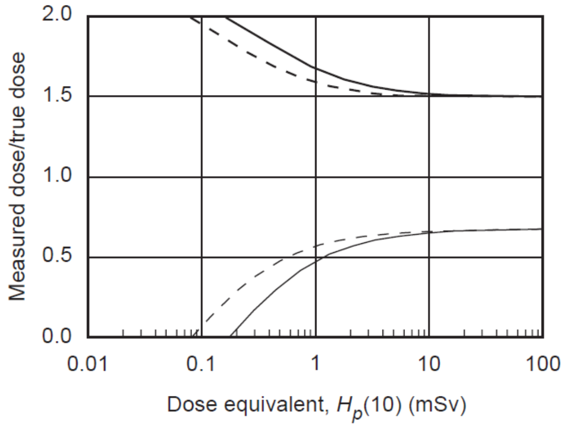


Figure 1 Trumpet Curve (International Atomic Energy Agency, 2018).

To determine the upper and lower limits of the Trumpet Curve, Equations 2 and 3 were used.

$$R_{UL} = 1.5 \left[ 1 + \frac{H_0}{2H_0 + H_1} \right] \quad (2)$$

$$R_{LL} = \frac{1}{1.5} \left[ 1 - \frac{2H_0}{H_0 + H_1} \right] \quad (3)$$

$H_0$ is the lowest dose that needs to be measured; $H_1$ is a true conventional-dose given before. Based on the ICRP No. 60, the value of $H_0$ is 0.17 mSv.

## 3. METHOD

### 3.1 Equipment

The radiation source used was Cs-137 and X-ray beam. Cs-137 beam Irradiated from the Buchler OB-85 machine. This machine was made by Buchler GmbH, with the activity was 74 GBq, at reference time (May 1985). For the X-ray beam, XYLON 325 machine was used. This X-ray generator machine has a maximum of 320 kVp, 22.50 mA, and 120 minutes irradiation times.

The detector was ionization chamber 600 $cm^3$ series 576 from Nuclear Enterprise (NE) connected with PTW Unidos Webline T10022/268 electrometers for the dosimetry system. The ionization chamber 600 $cm^3$ has a calibration factor traced to BIPM through SSDL International Atomic Energy Agency (IAEA).

### 3.2 Determination of Air Kerma Rate for Cs-137 and X-ray Beam

The source to detector distance (SDD) used was 200 cm in this irradiation procedure. The ionization chamber 600 $cm^3$ was used to determine the air Kerma rate for Cs-137 and X-ray beam. The ionization chamber measured the charged particle (nC), and then with the calibration factor (µGy/nC) the air Kerma rate can be determined.

The same procedure was done for the determination of the air Kerma rate for an X-ray beam with N-80 radiation quality. The specifications for X-rays with N-80 beam quality were obtained by adjusting the tube voltage to 80 kV, HVL as thick as 0.59 mm Cu, and adjusting additional filters as 2.028 mm Cu (Firmansyah, 2020). This filter was verified under the requirement given by the calibration certificate published by SSDL IAEA. It was also traced to ISO 4037 for X-ray beam qualities.

### 3.3 Irradiation Individual monitoring dosimeter for $H_p(10)$ dan $H_p(3)$

After the air Kerma rate in each radiation beam was determined, the individual equivalent dose rates of $H_p(10)$ and $H_p(3)$ can be determined. The individual equivalent dose rate can be determined by multiplying the air Kerma rate (mGy/min) with the conversion factor (Sv/Gy). The conversion factor for the amount of $H_p(10)$ and $H_p(3)$ was 1.88 and 1.66 mSv/Gy, respectively. The conversion factor can be found on the IAEA publication Safety Report Series Calibration of Radiation Protection Monitoring Instrument (SRS-16).

For example, in the 2018 intercomparison activity, the $H_p(10)$ and $H_p(3)$ dose rate for X-ray N80 obtained value of 0.64 mSv/min ± 3.1% and 0.561 mSv/min ± 3.1 %, respectively. The $H_p(10)$ dose rate for the Cs-137 radiation beam was 0.133 mSv/min ± 3.1%.

Individual dosimeter irradiation was done by setting the TLD/film to the surface of water phantom (30 cm x 30 cm x 15 cm) for the amount of $H_p(10)$ and water pillar phantom called Oramed with a diameter of 20 cm and a length of 20 cm for the amount of $H_p(3)$. Irradiation was carried out for specific dose values for the amount of $H_p$ (10) with a dose value of 2 mSv, eight mSv, ten mSv, and eight mSv for the amount of $H_p(3)$.

A dosimeter package consists of 4 TLD/ film badges to be irradiated with a specific dose while another set of TLD/film dosimeters as a control (not irradiated).

For confidentiality purposes, the participants' names were not listed in this paper. The total number of intercomparison activities in 2018 was 36 TLD consisting of 14 packages of $H_p(10)$ Cs-137, 14 sample packages of $H_p(10)$ X-ray, and 8 sample packages of $H_p(3)$ X-ray. Meanwhile, the total number of intercomparison activities in 2019 was 24 TLD packages consisting of 2 sample packages of $H_p(3)$ X-ray, 11 sample packages for $H_p(10)$ X-ray, and 11 samples packaged for $H_p(10)$ Cs-137.

Table 2 The Amount of TLD Sample Package.

| Year | Type | Radiation Beam Type | |
|---|---|---|---|
| | | Cs-137 | X-Ray |
| 2018 | $H_p(10)$ | 6 (film) & 8 (TLD) | 6 (film) & 8 (TLD) |
| | $H_p(3)$ | - | 8 (TLD) |
| 2019 | $H_p(10)$ | 2 (film) & 9 (TLD) | 2 (film) & 9 (TLD) |
| | $H_p(3)$ | - | 2 (TLD) |

### 3.4 Background and Transport Dose

As part of the intercomparison activity, the transportation of the TLD/film dosemeter should be considered an essential thing. It because when the dosemeter is transported by mail, it possible to get external irradiation from the environmental radiation or scanning process at the airport, etc. So, the control TLD/film will supply the information of transportation dose and calculated as background for the evaluation process.

## 4. RESULT AND DISCUSSION

TLD/film evaluation results for 2018 intercomparison for stated dose (performance test) with a dose value of 5.0 mSv in terms of Hp(10) X-rays, Hp(3) X-rays, and Hp(10) -Cs 137. The upper of the normalized reading value was 1.55 mSv, while the lower limit value was 0.62 mSv. It can be seen in Figure 2 that the results of the average evaluation of 36 TLD/film packages for the Hp(10) and Hp(3) under X-ray and Cs-137 irradiation conditions were still within the acceptable range. However, there was one sample in which the results were approaching the lower limit, which was 0.67 mSv.

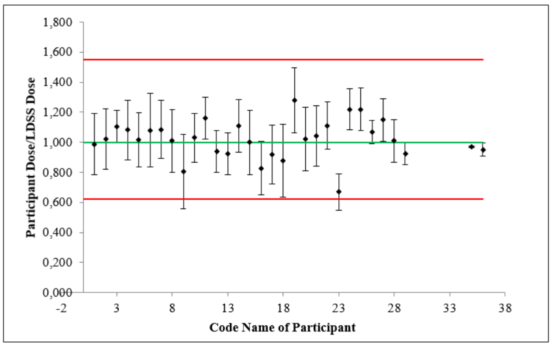


Figure 2 Evaluation result for a performance test of $H_p(10)$ X-ray (Intercomparison 2018).

Besides, TLD/film evaluation results for unknown doses (blind test) in terms of $H_p(10)$ irradiated with X-rays can be seen in Figure 3. The lower limit was 0.64 mSv, and the upper limit was 1.53 mSv.

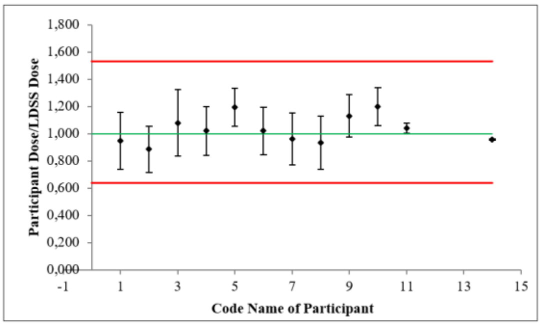


Figure 3 Evaluation result for the unknown *test* of $H_p(10)$ X-ray (Intercomparison 2018).

Meanwhile, the results of evaluation TLD/film readings of Hp(3) X-ray for unknown doses (blind test) can be seen in Figure 4. The lower limit was 0.64 mSv, and the upper limit was 1.53 mSv. There was one measurement below the lower limit with 0.63 mSv as a normalized value.

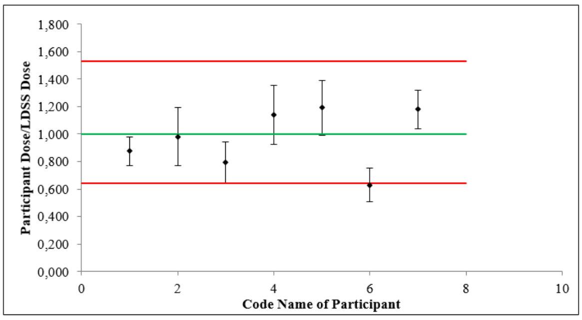


Figure 4 Evaluation result for the unknown test of $H_p(3)$ X-ray (Intercomparison 2018).

The evaluation results for unknown doses (blind test) of Hp(10) with the source of Cs-137 irradiation can be seen in Figure 5. The evaluation has known good average results, within the upper and lower limits of reading normalization. The lower limit was 0.56 mSv, and the upper limit was 1.61 mSv.

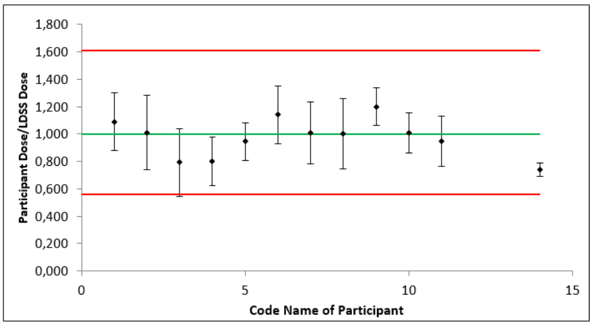


Figure 5 Evaluation result for unknown test of $H_p(10)$ Cs-137 (Intercomparison 2018).

For the intercomparison in 2019, Figure 6 shows the evaluation results for the blind test of Hp(10) irradiated with X-rays. The lower limit was 0.60 mSv, and the upper limit was 1.58 mSv. Based on the graph, it can be seen that the results of the normalization of readings get appropriate values.

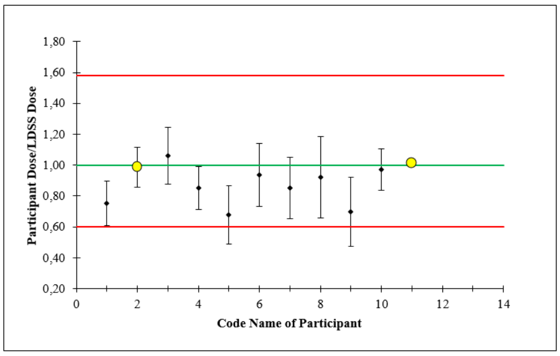


Figure 6 Evaluation result of unknown test of $H_p(10)$ Cs-137 (Intercomparison 2019).

The blind test evaluation of $H_p(10)$ and $H_p(3)$ irradiated with X-rays for intercomparison activities in 2019 can be seen in Figure 7. The lower limit was 0.64. mSv and the upper limit of 1.53 mSv. There were two data whose approaches the lower limit with a value of 0.674 mSv and overestimate the upper limit with a value of 1.56 mSv.

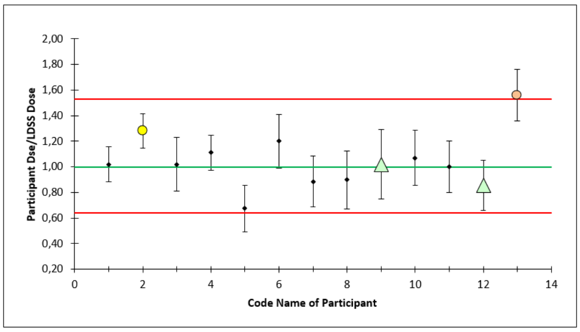


Figure 7 Evaluation result of $H_p(10)$ dan $H_p(3)$ X-ray (Intercomparison 2019).

The two test methods for the stated dose (performance test) and unknown dose (blind test) were used to test the participants' performance. It will make the participants more earnestly to do the evaluations TLD/film under the reference procedures.

Based on the IAEA TEC-DOC 1126, the dosimetry system's performance will be considered satisfactory if the evaluation result lies in the trumpet curve with 95% of the dosimeter. A few publications used the trumpet curve as the reference to judge whether the evaluation results are in an acceptable range or not (Adjei et al., 2017; Arib et al., 2014; Msimang et al., 2011).

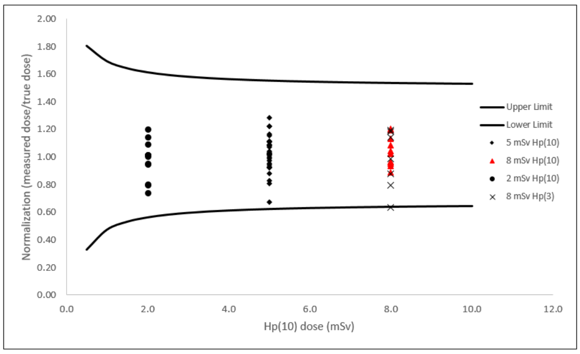


Figure 8 Trumpet Curve for Intercomparison 2018.

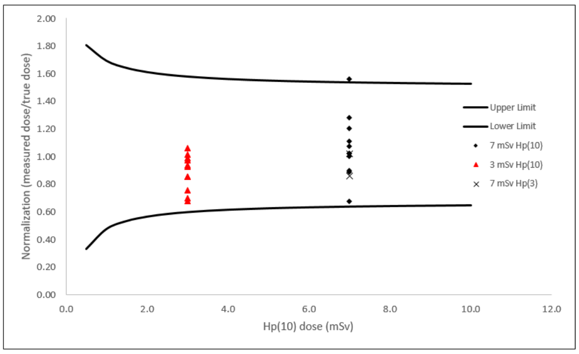


Figure 9 Trumpet Curve for Intercomparison 2019.

Figures 8 and 9 show the trumpet curve for the evaluation result in 2018 and 2019 for Indonesia's dosimetry laboratory network. The overall intercomparison 2018 and 2019 were still the same, but there was a difference in the amount of TLD/film sent to SSDL as coordinator. It because the performance test has been deleted. So, it made the amount of TLD/film to send has decreased. The reason for this was the effectiveness of the activity as the result of meeting at intercomparison 2018. However, the quality of the program was maintained well to ensure the outcome.

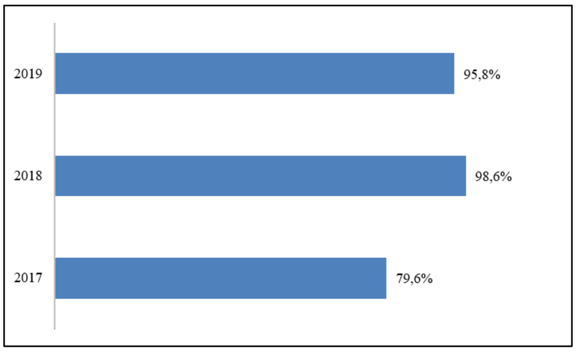


Figure 10 The result of intercomparison activity at 2017-2019.

In this case, the intercomparison activities in 2018 experienced an increase in the success rate from 2017, which got a success rate of 79.6%(Firmansyah, 2017). Nevertheless, the success rate decreased by 2% in 2019, with a success rate of 96%.

The error factor in handling film dosimeter readings can be the cause of the evaluation result in having a significant deviation from the given value. Aya(Aya Mahmoud Hamdy Abaza, 2018) stated in her publication that film (radiographic film) response depends on several parameters, which is difficult to control. According to Hansel S (Hasnel Sofyan, 2012) in his publication, film dosimeters also have the characteristics of dependence on the level of humidity and temperature and have a high level of fading because of the time delay. The evaluation process by the processing laboratory was carried out after sending the SSDL by mail. The temperature and humidity factors in the postal delivery process cannot be controlled and can cause the film dosimeter to be centralized or unfavorable to read/evaluate.

Based on that, the author recommends that the use of film be replaced with the use of TLD as an individual dosimeter in the future. In addition to being used for the long term, TLD also has several advantages compared to film dosimeters, such as higher sensitivity, dose reading resolution <1 mGy, and not influenced by the level of high humidity and magnetic field. Besides TLD, optically stimulated luminescence (OSL) dosimeters can also be used as individual dosimeters (Butler et al., 2018; Jumpeno et al., 2017; Kurasawa et al., 2017).

Although the success rate decreased in 2019, the overall acquisition of intercomparison activities is excellent because it can maintain good evaluation results over the 95% success rate. This result is proved of the quality of personal dose equivalent $H_p(10)$ and $H_p(3)$ in Indonesia for the last three years.

There is still a need to be upgraded for the intercomparison program for the next agenda. Until the last intercomparison activity, the test was about performance for the evaluation of a specific dose. It can be added, such as the linearity verification, the energy response, and the angular response.

## 5. CONCLUSION

This study aims to analyze the intercomparison activity in measuring the quantity of personal dose equivalent $H_p(10)$ and $H_p(3)$ for the dosimetry laboratory network in Indonesia.

The results of evaluations from nine laboratories participating in the intercomparison activity for equivalent individual doses of $H_p(10)$ and $H_p(3)$ quantities using TLD/film in 2018 - 2019 get excellent results. All of the results from participants were in the acceptable range. These results indicate a superb acquisition for evaluating doses and the competency of the officers working to conduct the evaluation.

Due to this achievement, it is possible to apply an upgrade of the next intercomparison testing method, i.e., the angular response, the energy response, and the linearity verification.

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