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Worker Health Monitoring Through Whole Body Counter Examination for Safety and Radiation Protection (2017-2019 Data)

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Abstract

Radiation protection is an action or effort taken to reduce the effects of damaging radiation exposure. Therefore, it is necessary to routinely monitor the condition of workers, among others, with a whole-body counter (WBC) either for daily activities or in a radiation emergency. In this research 78 male and female workers with an average age of 44.51 years old who have been worked for 1 up to more than 30 years at the Center for Technology of Radiation Safety and Metrology (PTKMR) - BATAN in 2018-2019 have been determined with standard procedures. The results showed that the average K-40 count for the year 2018 was 3767.35 ± 975.33 Bq. Among the 80 participants tested, internal radio-isotopic contamination with Cs-137 was detected in one person, but the levels were marginal and just exceeded the detection limit (250 Bq/body). This average value was lower than that of the previous year (2017) i.e. 4274.74 ± 740.85 Bq for 43 respondents. There is no positive correlation between radioactivity with the bodyweight of respondents but correlated positively with body mass index. It is concluded that the radio-activities of the workers of PTKMR are still within a normal range.

Introduction

Currently, the use of nuclear energy and technology is very broad, covering almost all aspects of human life, for example the fields of health, industry, space, agriculture, and energy generation (Brook, et al., 2014; Bielecki, 2020). The application of radiation in these various fields is certainly accompanied by health risks for its workers. Various radiation effects, both deterministic and stochastic, are well known. To prevent and reduce the effects of radiation, protection measures must be made in every radiation application, including monitoring the health of radiation workers (Wunderle, 2015). The main objective of radiation worker health surveillance is to assess the fitness of the worker at baseline and during work related to radiation sources (Ko, 2017).

Radiation safety and protection is a branch of science related to medical engineering, namely the protection that needs to be given to a person or group of people against the possible negative effects of ionizing radiation, while the activities required to use ionizing radiation sources are still being carried out (Desouky & Ding, 2015). Currently for this purpose monitoring tools and methods have been used such as physical dosimeter satisfactory (Watanabe, 2017). This is supported, among other things, by implementing a dose limit value (NBD). NBD is the largest dose permitted by the supervisory agency (Nuclear Energy Supervisory Agency, BAPETEN) which can be received by radiation workers and members of the public within a certain period of time without causing significant genetic and somatic effects due to the use of nuclear energy (Desouky & Ding, 2015). However, radiation workers have the potential to receive unwanted radiation exposure either exceeding or not exceeding the permitted NBD, as a result of an accident or due to incorrect work procedures.

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Immediately after exposure to excess radiation, management should carry out investigations to determine the dose received by workers. If the dose is known, the damage or contamination will occur, then it must be informed to the occupational health service. If an excessive dose of irradiation is suspected to have the potential to have a negative impact on the health of radiation workers, additional health checks are necessary (Vaiserman, 2018).

To reduce health threats and avoid unwanted radiation exposure, accurate assessment of the radiation exposure of workplace workers or residents living in radioisotope contaminated areas is necessary (Yasumura, Hosoya, & Yamashita, 2012). Ionizing radiation which affects living systems can produce a range of biological outcomes including inflammation, tissue injury, carcinogenesis and death (Reisz, 2014; Nakamura, 2013). Although radiation accidents are highly rare these days, the situation that arises will be very serious. Various ways can be done to monitor the health of workers, including Thermo Luminescence Dosimeter (TLD) for external exposure (Botwe, 2015), blood chromosome examination (Perumal, et al., 2015; Bi, 2019), examination through urine analysis (bioassay) (Yoo, et al., 2016), whole body counter (WBC) (Shimmura, 2015), etc. with their respective advantages.

Whole Body Counter (WBC) is a device for measuring radioactivity in the human body. This technique is primarily intended for radioactive materials that emit gamma rays. Alpha particle decay can also be detected indirectly by the coincidence of gamma rays. Under certain circumstances, beta yields can also be measured, but with less sensitivity (Shimmura, 2015). In nuclear facilities, these counters are used to measure radioactivity in the human body, that is to say, for the measurement of internal contamination. Full-body counters are highly sensitive devices and are therefore often surrounded by a large amount of lead shielding to reduce background radiation. The full body counter consists of, for example, a standing booth stand with two large area NaI scintillation detectors (Hosokawa, 2017). Whole body counting has been directed towards two uses, firstly, with regard to detection and measurement of trace amounts of radioactivity naturally or inadvertently in the body (accident), and second, with regard to the absorption and retention of radionuclides administered for diagnostic or therapeutic purposes (Yonekura, et al., 2019). Currently health physicists in many laboratories use a total body count (WBC) to estimate the body burden of radioactive material. Direct external measurement with WBC is in most cases with more convenient and accurate method than estimating body load from excretion data. The purpose of this study was to estimate the body load of radionuclides in a number of workers at PTKMR in 2017-2019.

Methods

This research was conducted at the Center for Safety Technology and Radiation Metrology, BATAN Pasar Jum'at, South Jakarta. The research was started in August - November 2017 and 2018. The equipment used was Horizontal Bed Whole Body Counter Model 2260, ACCUSCAN brand, product of CANBERRA Industries at PTKMR. This equipment is a full-body counting system, equipped with a turn-key. This system identifies and measures radioactivity in the human body in a matter of five to eight minutes. The enumeration is done after the WBC is calibrated, which includes energy calibration, FWHM (Full Width Half Maximum) calibration and efficiency of calibration. After the equipment has been calibrated, a respondent census is carried out where the instructor provides a brief explanation to the respondent about the implementation of the measurement. Respondents are expected to position themselves on the bed on the WBC device lying on their back, and be calm and not move much during the examination, namely census for 10 minutes. The spectrum of the census results is stored in a file and then analyzed to calculate the sample activity in two ways, namely program (software) and manually. For the calculation of activity with software, the spectrum of the sample or respondent count results is analyzed using 3 calibration equations that have been done previously, namely energy calibration, FWHM and efficiency. After the program processes the data, the results will be obtained in the form of: the type of radionuclide, energy and activity of the sample or respondent being enumerated.

For manual counting, the area of the peaks is determined from the spectrum of the existing peaks, then the count per second (cps) is determined by dividing the area by the length of the count in second units. With equation [I], the activity of the chopped sample can be calculated. The detection efficiency values used in manual calculations are the same as those used in software calculations. Next is the spectrum analysis of the census results and recording the results on the Radiation / Nuclear Accident Examination Form.

Results and Discussions

The results of the calculation using software and manual are shown in Figure 1. From the figure, it can be seen that the activity resulting from the calculation of the software is always greater than the activity of the enumerated sample; this is due to an error in the parameters in the software used to analyze the spectrum of the census results so that improvements are still needed. The accuracy of the tool is also greater according to the increase in energy of the chopped sample. For whole body chopping with standard sample Cs-137, the accuracy level is 83.95%.

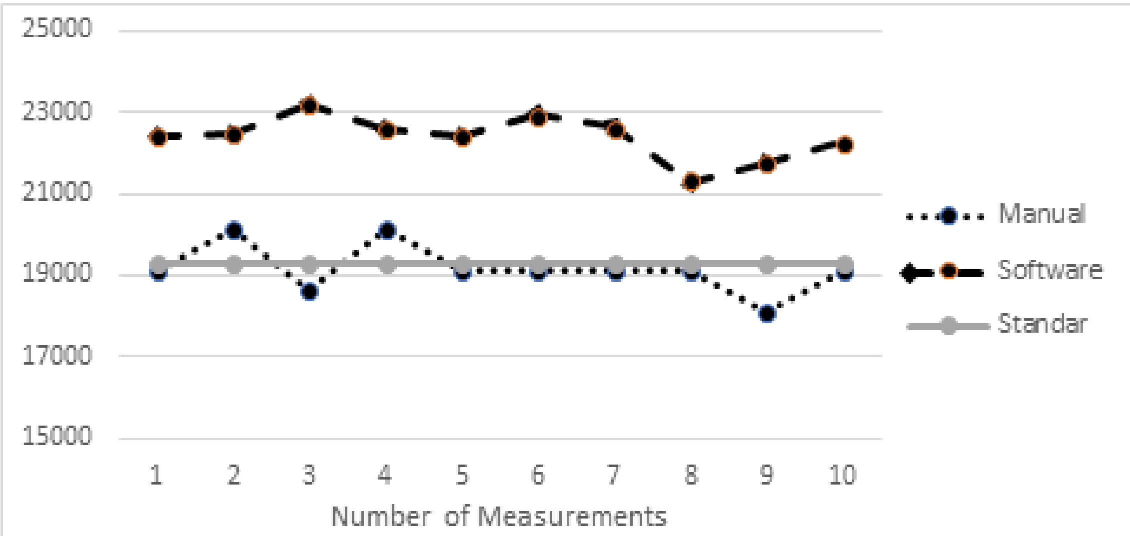

Figure 1. Software and Manual Calculation Activities for Whole Body Counting were Compared with Standard Source Cs-137 = 19,300 Bq

The measurement results show that the average count of K-40 radionuclides from 78 respondents for 2018 is 3768.64 ± 973.55 Bq. This result is still in the normal category or is still below the specified limit. Among the participants tested, one worker had detected radioisotope Cs-137 contamination, but the level was still within safe limits and only slightly exceeded the detection limit (250 Bq/body). The average value of this measurement is lower than the results of the previous years monitoring (2017), namely 4274.74 ± 740.85 Bq for 43 respondents (Table 1). There was no positive correlation between body weight and K-40 activity for each respondent. An example of the counting results of a respondent showing the measured isotope peaks is presented in Figure 2.

Table 1. The Average Value of K-40 (Bq) Radioactivity Measurements with WBC for PTKMR Respondents in 2017 and 2018

Year	Number of Respondents	Male/Female	Age	Activity of K40 (Bq)
2017	43	23/20	46.51 ± 9.82 (25 - 60)	4274.74 ± 740.85 (2550 – 5510)
2018	78	42/36	44.39 ± 12.67 (22 – 60)	3768.64 ± 973.55 (2045 - 6088)

Source: Primary Data, 2018

Referring to the maximum allowable limit (i.e. 370 Bq/kg) (Darwish et al., 2014), the amount or activity obtained in this study is still far from this limit. For example, for 2017 where the average activity was 4274.74 Bq for 65.97 kg, the activity would be 64.79 Bq/kg, while for 2018 it was 57.26 Bq/kg.

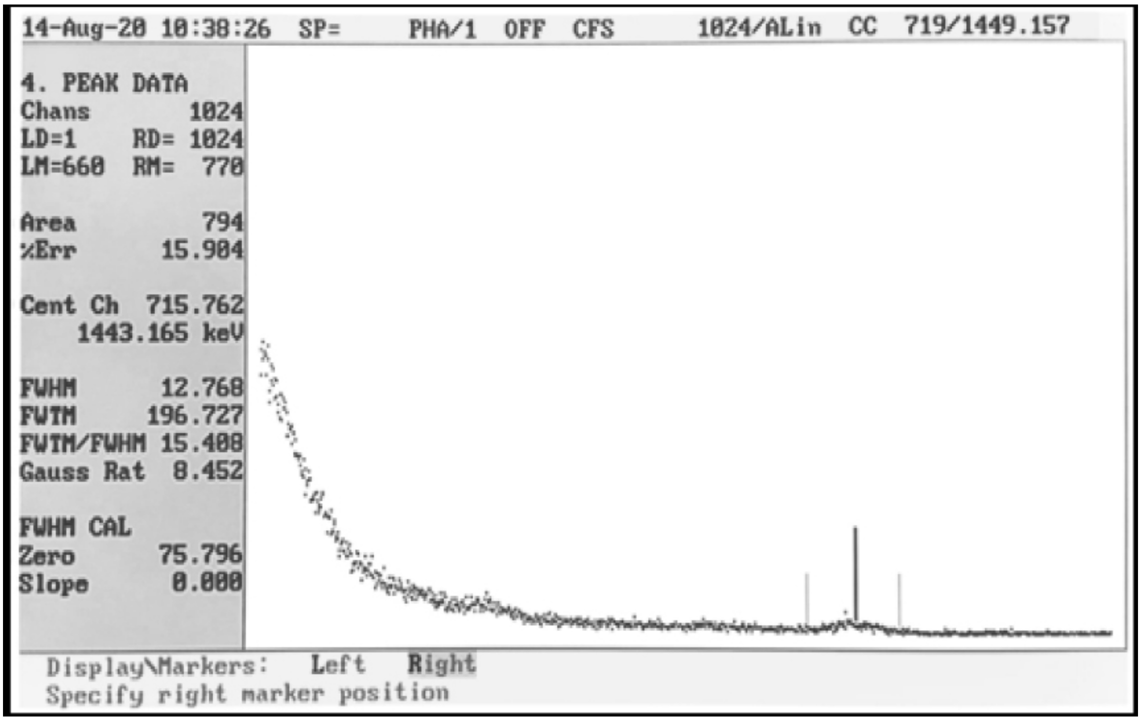

Figure 2. An Example of a Census Result of a Respondent with WBC Showing Isotope Peaks (Especially K-40 at 1400 keV) Measured with the Lowest and Highest Range (ROI).

If all data are combined for 2017 and 2018, it is known that with regression analysis there is no positive correlation between radioactivity and the respondent's age with a relationship of $y = -2.1016x + 4006.5$ with $R^2 = 0.0007$, but there is a positive correlation with body mass index with a relationship of $y = 52.188x + 2584.8$ where $R^2 = 0.0442$ (Figures 3 and 4).

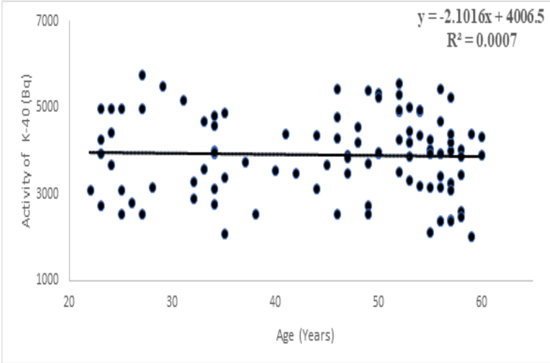

Figure 3. The Results of the Regression-correlation Analysis Between Radioactivity (Bq) and the Age of the Respondent (Years)

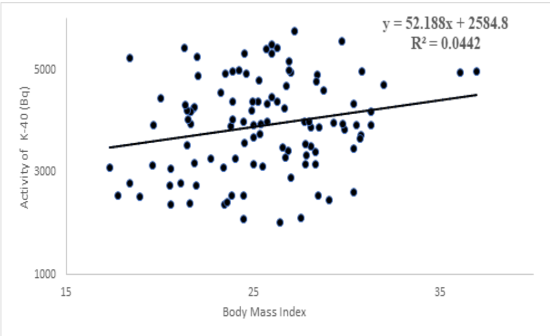

Figure 4. The Results of the Regression-correlation Analysis between Radioactivity (Bq) and the Body Mass Index

In this paper, the measurement of internal radioactivity in the body of a worker has been discussed or investigated. Internal dose measurement is an important part of the WBC monitoring system for monitoring internal dose radiation exposure levels for radiation workers and the public. Workers handling radioactive substances are susceptible to external and internal contamination; hence the need for a radiation protection program that monitors them monthly or annually depending on their needs. Meanwhile, public concerns about contamination arise when an accident occurs at a nuclear facility such as the accident at the nuclear power plant in Fukushima, Japan. For detection and measurement of internal contamination due to fission/ activation products emitting gamma such as Cesium-137, Cobalt-60 and Iodine-131, bed and chair type full-body counter monitoring systems are widely used worldwide. WBC or other radiation counters are used to detect radiation emitted by combined radionuclides during occupational exposure, as well as for response readiness in cases of Radiological Emergencies (Singh I S, 2016; Wada, et al., 2017).

Several WBC devices have been used to monitor internal radioactivity in cases of worker contamination. However, it has been found that external contamination is sometimes thought of as internal contamination in whole-body radioactivity calculations. Therefore, the amount of radioactivity detected can be much higher than the actual radioactivity due to this misclassification of contamination, because the radioisotope stuck to the skin is in close proximity to the WBC detector. Finally, this not only leads to the misjudgment of external contamination as internal contamination, but also an overly conservative estimate of radioactive contamination (Kazzi, 2015).

Whole-body dose calculation, at least in its clinical application, may be a procedure that is not too distinct and separate from previous procedures. The increased use of these procedures is predicted to increase in current and future programs of radiation safety, nuclear medicine, and biomedical research. In this study, the number of isotopes in the respondent's body was determined. The factors that determine the relative radiation hazard of radioisotopes are their quantity, initial body retention, fraction flowing from blood to critical organs, tissue radio-sensitivities, critical organ size, essentiality of an organ, biological half-life, radioactive half-life which is approximately equal to average human lifespan, effective energy per disintegration, and specific ionization (Sinnott, 2010).

In terms of K-40, measurements of the specific activity of the population in the Egyptian Sinai desert were found to range from 940.6 to 1323 Bq/kg with a mean of 1186.4 Bq/kg, which is three times higher than the limit (370 Bq/kg) (Darwish, Abul-Nasra, & El-Khayatt, 2014). Another study by Tolstykh et al. showed that the K-40 activity was 4200 Bq in male and 3000 Bq in women respondents in Russia. Meanwhile, the results of measurements on the general population in Bangladesh showed that the potassium content ranges from 101-196 gK (Patwary, 2013). Another study in the same country conducted by Rahman et al. found that the K-40 content for men was 2000 Bq/kg and for women was 1700 Bq/kg, averaging 1900 Bq/kg. Meanwhile, the results of measurements of K-40 radioactivity in Russia showed that for respondents aged 20–50 years, it is known that 4200 Bq for men and 3000 Bq for women, where this activity decreases with increasing age (Rahman, 2008; Tolstykh, 2016). These results were consistent with the statement that the amount of radioactive K-40 isotope for a person weighing 70 kg is about 5,000 Bq (Toohey, 1983).

According to the IAEA-TECDOC, all minerals and raw materials contain radionuclides of origin which are highly radioactive up to 4000 Bq/kg (Masok, 2016). In addition, the most important radionuclides for radiation protection purposes are the whole children U-238 and Th-232 as well as K-40. Thus, this research is higly important to be carried out routinely because occupational exposure can lead to the introduction of radionuclides into the body which can occur as a result of various activities, including work related to various stages of the nuclear fuel cycle; use of radioactive sources in medicine, scientific research, agriculture and industry; and work involving exposure to increased concentrations of natural radionuclides (Joyce, 2017).

Radiation exposure that is harmful to the health of workers is not only internal exposure, but also external exposure. Devices that emit radiation will pose a risk of danger to workers who use these tools, for example radiographers, cathlab doctors, X-ray equipment operators, radiologists and so on. This exposure can directly penetrate cells and cause damage to the body at the molecular level. Several previous studies have shown that there is a significant relationship between the dose received and the increase in micronuclei frequency as one of the biomarkers of DNA damage in radiation workers in several government hospitals in Indonesia. The increase in micronuclei frequency reached 16.3 for every 1 mSv increase in exposure dose, whereas for radiotherapy patients, higher micronuclei frequencies were also found than controls. Of course, the cellular DNA damage is not only influenced by the type and dose of exposure, but also individual factors, such as age, sex and smoking habits (Surniyantoro, Lusiyanti, Rahardjo, Nurhayati, & Tetriana, 2018; Surniyantoro, et al., 2019; Surniyantoro, et al., 2018). Exposure to ionizing radiation is also a risk factor for breast and cervical cancer (Sriningsih & Elisa, 2017)

Levels of blood components are also affected by radiation exposure. The number of red blood cells and monocytes in the blood was found to be significantly higher in the radiation worker group than in the control group, while the white blood cell count, hematocrit, mean corpuscular volume and lymphocytes were lower in radiation workers. In correlation-regression, an increase in the number of red blood cells in radiation workers was 0.541×106 / μL for every 1 mSv increase in the exposure dose. These various possible hazards should be considered and paid deep attention to radiation workers and related stakeholders in any activity that uses nuclear energy so as to create a safe, comfortable and safe work environment (Surniyantoro, et al., 2019).

Conclusions

It is concluded that the K-40 radioactivity among workers in PTKMR is still within the normal limits which for 2018 is lower than the previous year. There is no positive correlation between respondent body weight and radioactivity.

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