

ISSN 2721-2300



Volume 1 (2020)

# PROCEEDING

of International Conference  
on Nuclear Capacity Building,  
Education, Research and Applications

Yogyakarta, Indonesia | September, 6<sup>th</sup>-7<sup>th</sup> 2019



Indonesia  
Nuclear Expo  
**2019**

Publisher  
Badan Tenaga Nuklir Nasional

## **Preface**

The International Conference on Nuclear Capacity Building, Education, Research and Application, **I-Concern'19**, organised by the National Nuclear Energy Agency (BATAN), was held in Yogyakarta, Indonesia on September 6 – 7, 2019. This conference which is a part of the Indonesia Nuclear Expo (**NEXPO**) 2019 event was a fruitful and successful scientific gathering between lecturers, researchers, academics, practitioners and communities, medical specialists, industries, government, and the public on exploring the nuclear technology in terms of human resources, applications, technology, policies, and innovation.

The two days program of I-Concern'19 accommodating 7 keynote and 18 invited speakers, and 108 contributed talks in Plenary and Parallel Sessions. At the same time, 144 posters were also presented in the 2 Poster Sessions, while 15 vendor exhibitors displayed their commercial products on nuclear medical applications, nuclear instrumentation, NDT equipment, and other products. In total, 250 presenters and 37 observers coming from 9 countries of 3 continents had been gathering for the 2 days of the conference.

From this conference, we received 234 manuscripts. All of them have been intensively reviewed and have been decided by the Chief of Editors to publish 145 papers in the IOP Journal of Physics Conference Series 2020, Volume 1436. Other manuscripts were published in the Jurnal Forum Nuklir 2020, Volume 40 (6 papers), Indonesian Journal of Materials Science (Jusami) 2020, Volume 21 (4 papers), and in this Conference Proceeding (79 papers).

We are very much grateful to the esteemed members of the International and Local Advisory Committees for their advice and guidance, the supports from the National Nuclear Energy Agency (BATAN) in collaboration with the Indonesian Society for Nuclear Medicine (PKNI), the International Atomic Energy Agency (IAEA), the Ministry of Health of the Republic of Indonesia, National Standardization Agency of Indonesia (BSN), the World Federation of Nuclear Medicine and Biology, the Clarkson University, USA. We also gratefully acknowledge the sponsorships.

We hope that the present proceedings provide the valuable information to the readers in the field of nuclear science, technology, innovation and human resources development.

March 27, 2020

Edy Giri Rachman Putra, Ph.D  
*Chairman of I-Concern '19*



### **Conference Chair**

Edy Giri Rachman Putra, Ph.D

### **International Advisory Committee**

Prof. Amirreza Jalilian, Pharm D, PhD (International Atomic Energy Agency)

Prof. Dr. Dong Soo Lee (World Nuclear Medicine and Biology)

Prof. Dr. Philippe Hopke (Clarkson University, USA)

Prof. Hiroyuki Miyamoto (Doshisha University, Japan)

Dr. Somchai Tancharakorn (Synchrotron Light Research Institute, Thailand)

Dr. Myungkook Moon (Korea Atomic Energy Research Institute, Korea)

Dr. Bin Fei (Institute of Textile and Clothing, Hongkong Polytechnic University)

### **Local Advisory Committee**

Prof. Dr. Ir. Anhar Riza Antariksawan

Ir. Falconi Margono Sutarto, MM

Prof. Dr. Ir. Efrizon Umar, M.T

Dr. Hendig Winarno, M.Sc

Ir. Suryantoro, M.T

Drs. Totti Tjiptosumirat, M.Rur.Sci

Dr. Jupiter Sitorus Pane, M.Sc

Drs. Budi Santoso, M.Eng

Ir. Ruslan

### **Scientific Programme Committee**

Dr. Muhammad Rifai, M.Eng

Dr. Emy Mulyani

Prof. Drs Darsono, M.Sc

Dr. Darmawan, Apt

Dra. Mujamilah, M.Sc

Dr. Muhtadan

Isti Daruwati, M.Si

Dr. Sobrizal

Dr. Irawan Sugoro, M.Si

Adi Abimanyu, M.Eng

Dr. Basuki Hidayat, dr., Sp.KN (K)

dr. Nopriwan, SpKN

dr. Hendra Budiawan, SpKN (K) FANMB

### **Editorial Team**

Dr. Muhammad Rifai, M.Eng

Dr. Emy Mulyani

Haerul Ahmadi, M.Si

Ayu Jati Puspitasari, M.Si

### **Guest Editors**

Prof. Dr. Dani Gustaman Syarif

Dr. Imam Kambali

Drs. Djoko Slamet Pudjoraharjo

Dr. Taufik

Tjipto Sujitno, M.T  
Mahrus Salam, M.Sc  
Ir. Theresia Rina Mulyaningsih, M.Si  
Drs. Tri Hardi Priyanto, M.T  
Agus Salim Afrozi, M.T  
Ir. Bagiyono, M.Sc  
Dr. Adel Fisli  
Dr. Andon Insani, M.Eng  
Dra. Auring Rachminisari  
Dr. Jan Setiawan, M.Si  
Dr. Marzuki Silalahi  
Ir. Sucipta, M.Si  
Dra. Grace Tjungirai Sulungbudi, M.Sc  
Dr. I Putu Susila  
Dr. Mukh. Syaifudin

**Local Organizing Committee**

Haerul Ahmadi, M.Si  
Ayu Jati Puspitasari, M.Si  
Halim Hamadi, M.Sc  
Lutfi Aditya H, M.Sc  
Aris Bastianudin, M.M  
Lutfi Syarif Ahmad, SAB  
Ardina Mei Devinta Suryana, SST  
Thomas Chandra Andrian, SST  
Oksi Widiantonono, A.Md.T  
Fauzi Maulana Rachman, SST  
Sinta Uri El Hakim, SST  
Royan Novi Amar, SE  
Ajie Noorseto, S.Kom  
Wens Roland

## Contents

### Preface

Foreword	ii
Committee	iv
Content	vi

### Papers

Design of determination system of current and voltage levitation on prototype maglev conveyor using fuzzy logic <i>Fahriza, Supriyono, and A J Puspitasari</i>	1
Analysis of image result in aluminium and steel plates using digital and conventional radiography <i>Z Abidin, K T Basuki, Suroso, J Atri, and T Mulyono</i>	8
Development of an auxiliary software for WIMS input file creation as a means of calculating the critical mass of the Kartini reactor <i>P H Sadewo and P I Wahyono</i>	16
Exploring the potential of sorghum for food, animal feed and bioenergy through induced mutation breeding <i>Sihono, H Soeranto, M I Wijaya, Y M Marina, W Puspitasari, and T Wahyono</i>	22
Stopper and construction joint on shielding for the irradiator building in Indonesia <i>H Saptowati, A R Yanto, T Wahono, and Praptana</i>	29
Analysis of temperature distribution of cooling water for Co-60 source to gamma irradiator safety <i>Sanda, Kasmudin, and S Ramdja</i>	37
Study of gamma heating of the topaz irradiation using B <sub>4</sub> C container and stringer <i>A Sunardi, R Mahardika, A Rohanda, M Alfarisie, K Mustofa, and Camelia</i>	47
Synthesis and selectivity of benzotriazolium-based room temperature ionic liquids for technetium-99m separation from molybdenum by IL-mediated liquid-liquid extraction process <i>Y Setiadi, M B Febrian, A Mudzakir, A Aziz, D Setiawan, A K Illahi, and D A Rahmawati</i>	53
Fabrication of Fe-17Cr-25Ni ODS steels using arc plasma sintering method <i>R Salam, A Dimiyati, M Dani, Sumaryo, and N Shabrina</i>	60
Wattmeter development on the laser LED power supply as a supporting tool for basic research on gold nanoparticles-based photothermal cancer therapy <i>F A Wibowo, A Pujiyanto, M Subechi, A H Gunawan, I Listyowati, R Soetikno, and M Julita</i>	67
Synthesis of butyl bromide labelled <sup>82</sup> Br for leakage detection application in industrial pipeline system <i>A Suherman, T S Mulyati, I Iswahyudi, B S Rattyandanda, D Cartika, W P Silpia, M Hulupi, D Setiawan, and M B Febrian</i>	76
Software requirement specification (SRS) of nuclear education platform in android platform <i>F P Pangestu, F Nurfuadia, A Muslich, and W B Santoso</i>	83

Function and performance test of the device Glassman PS/OQ350RO10 model <i>Sukaryono, E Priyono, and A Dwiatmaja</i>	94
Neutronic characterization of training, research, isotope production by general atomic (TRIGA) reactor Bandung with modification plate fuel cladding using MCNP6 <i>A Andariska, Suharyana, F Anwar, Riyatun, Soeparmi, and A Khakim</i>	103
Study of PS/OQ350R018-model glassman high voltage to support the operation of 250 keV/10 mA EBM PSTA - BATAN Yogyakarta <i>E Priyono, Sukaryono, and A Susanto</i>	108
Comparison test of XRF and NAA methods for analysis of in-house monazite sand CRM candidate <i>S T Sunanti, Sukirno, and Samin</i>	120
The behaviour of RF generator for dee power supply in cyclotron DECY-13 <i>A Dwiatmaja, T Atmono, and Saminto</i>	126
Study of selective adsorption of activated charcoal for Technetium-99m from natural Molybdenum-99 for medical applications <i>H Setiawan, Sriyono, N Ahid, Hambali, A H Gunawan, Marlina, and M Munir</i>	131
Determination of the width of gamma radiation field of the OB-85 ( $^{137}\text{Cs}$ source) at calibration facility of PTKMR - BATAN <i>Nazaroh, O A Firmansyah, A F Firmansyah, and A Afham</i>	138
The relative threshold switching median algorithm to remove white spot noise and increase the homogeneity of neutron radiographic images <i>A Hindasyah, G S Sulistio, and Bharoto</i>	150
Analysis of heat capacity constant for SAMOP (subcritical assembly for $^{99}\text{m}$ o production) in Kartini reactor <i>A F Anugrah, Z E Bhagaskara, and W Karsono</i>	161
Improvement of radioscapy images by image averaging and temporal median filter <i>R Hijazi and J B Sulisty</i>	171
Test function after revitalization on water leaching units <i>Sudaryadi and Sajima</i>	178
Determination of elements content in neutron collimator before and after manufacturing using neutron activation analysis <i>A Budianto, Khoirunnisa, and Widarto</i>	183
Experimental study of natural convection valve detection system on Bandung research reactor <i>T S Santiko, K A Sudjatmi, and B Darmono</i>	196
Sensitivity curve for elements quantifying in soil samples on EDXRF MINIPAL 4 <i>N Adventini, D D Lestiani, W Y N Syahfitri, S Kurniawati, and E Damastuti</i>	200
Quality improvement of quartz crystal microbalance sensor using oleyl alcohol lipid membrane on HCl testing <i>I Tazi, A R Ummah, and Muthmainnah</i>	208
Testing of the secondary caprari refrigerator pump 1 TRIGA 2000 reactor Bandung <i>Koswara, Y Supriatna, and T Subekti</i>	212
An optimation of vacuum system for the cyclotron chamber DECY-13 <i>T M Atmono and K Wibowo</i>	220
High radiation chamber door design with pneumatic actuator <i>Y Yunus, D Priyantoro, and F T Nafisa</i>	224

Absolute standardization of $^{65}\text{Zn}$ by sum-peak method in PTKMR - BATAN <i>H Candra, G Wurdianto, and Holnisar</i>	236
Development of an android bases e-report apps in effectively managing complaints of any damage case in PSTBM-BATAN <i>E V Noviantana, Suyatno, and A Dimiyati</i>	240
Human tracking control system using Kinect sensors on wheelchair based on Arduino <i>H Hamadi, B Suhendro, M S Alamsyah, and M Ibrahim</i>	249
The design and construction of furnace for small angle neutron spectrometer <i>H Mугirahardjo, N Suparno, Saparudin, and A Insani</i>	250
Quality assurance and quality control at dose calibrator to support nuclear medicine services <i>Nazaroh</i>	254
Penentuan mass absorption coefficient black carbon pada berbagai panjang gelombang untuk identifikasi sumber pencemar <i>D P D Atmodjo, Supriyono, Muhayatun, dan S Kurniawati</i>	255
Improvement of Bangka's white pepper quality using gamma irradiation technology: microbial contamination reduction <i>D Darwis, T Puspitasari, N Nuryanthi, I Kadir, Wattiny, D S Pangerteni, and S Susilawati</i>	264
Leaching kinetics of sodium zirconate in hydrochloric acid based on shrinking core models <i>M Setyadi and Sudaryadi</i>	265
Indoor Radon measurements in Madura dwellings <i>Wahyudi, I D Winarni, and M Wiyono</i>	266
Sm-153 EDTMP for metastatic bone pain therapy in breast cancer <i>A Rumbiana, E A Pangarsa, and G Gunawan</i>	267
Simulation of water flow in a conduit using radiotracer-axial dispersion model <i>S Sugiharto</i>	271
Evaluation of customize syringe carrier box for transferring radionuclide Iodine-131 in nuclear medicine <i>A P Mukti</i>	272
Neutronic analysis of DECY-13 cyclotron target system as a neutron source for SAMOP <i>R F Isdandy, Syarip, Silakhuddin, K Wibowo, and Suharni</i>	273
Commissioning test of the Irradiator Gamma Merah Putih <i>A Satmoko, H A Gunawan, R Kardos, B Rozali, and M D Purwadi</i>	274
Qualitative analysis of long-lived residual radioisotopes in 18 MeV proton bombarded enriched water target <i>I Kambali, H Suryanto, Rajiman, Parwanto, F Rindiyantono, A A Billah, and Pasha</i>	275
Transmutation of $^{129}\text{I}$ containing nuclear waste by proton bombardment <i>I Kambali</i>	276
Alkaline comet assay as a predictor of DNA damage in medical radiation workers <i>H N E Surniyantoro, Darlina, and T Rahardjo</i>	277
Detection and measurement of obstacles on a track using color segmentation with background subtraction and morphological operation <i>H Hamadi, Supriyono, and D Riansah</i>	278
Accelerated purification of sorghum mutant line by using rapid cycling methods <i>W M Indriatama and Anisiyah</i>	279



Effect of projections number on the image quality of industrial parallel beam gamma tomography <i>B Azmi and M Stefanus</i>	280
The assessment of mitotic and nuclear division indexes as biomarkers for estimating the risk on the health of residents exposed to the high natural radiation of Mamuju, West Sulawesi <i>S Purnami, M Lubis, Suryadi, and M Syaifudin</i>	281
Planning and concept of borehole disposal technology for disposal of disused sealed radiation sources from using in health and industry <i>Sucipta and H A Pratama</i>	282
Characteristic of natural radionuclide in the rivers of Palembang, Pontianak, and Palangkaraya <i>G Suhariyono, I D Winarni, and J Mellawati</i>	283
Assessment of heavy metals pollution in the sediment of Ciliwung river <i>T R Mulyaningsih, M Irmawati, Istanto and Alfian</i>	284
Evaluation and assessment of 7 years of radioactivity monitoring data for Th-23, Ra-226, K-40 on surface soil and the impact of the construction of mass rapid transit stations around Pasar Jumat nuclear area <i>L Rixson, M Stefanus, and M Fajar</i>	285
Influence of blankets bore pile on soil characteristics Irradiator Gamma Merah Putih of Serpong <i>H Saptowati, T Wahono, Praptana, and A Bagas</i>	286
Elemental analysis of wepal sample using INAA in the framework of the 2017 IAEA proficiency test program <i>Sutisna, Alfian, and Istanto</i>	287
Determination of potassium in foodstuffs consumed in Mamuju Indonesia by neutron activation analysis <i>A H As'ari, S Yusuf, and T R Mulyaningsih</i>	288
Analysis of TRIGA 2000 core reshuffling scenario based on fuels burn up and fuels density <i>Nailatussaadah, P Basuki, and K Sudjatmi</i>	289
Occupational dose during an interventional radiology procedure <i>D Kartikasari, N Nuraeni, H Sofyan, and E Hiswara</i>	290
Non-destructive evaluation of nuclear grade IG-110 graphite using constant potential X-Ray <i>R Himawan, Sutrasno, and S B Santoso</i>	291
An analysis of the dee voltage of DECY-13 cyclotron based on a simple model <i>A H Shali, T M Atmono, and Saminto</i>	292
Study on technology of RF ion source for compact neutron generator <i>D S Pudjorahardjo and Suprpto</i>	293
Quality controls of radiolabeled compounds $^{131}\text{I}$ -Hippuran as PSTNT-BATAN product using electrophoresis method <i>T S Mulyati, E Rosyidiah, A Suherman, I Iswahyudi, and T H A Wibawa</i>	294
Validation and calibration of efficiency of various standard source for radioactivity analysis of gamma soil samples <i>D S Purnama and M K Akbari</i>	295
Stability of $^{131}\text{I}$ -Ortho-Iodo-Hippuric Acid ( $^{131}\text{I}$ -Hippuran) labelled compound produced by CANST (Center of Applied Nuclear Science and Technology) - BATAN Bandung <i>E Rosyidiah, T S Mulyati, A W T Hafiz, R J Sugiharti, and M E Sriyani</i>	296

Stability texture analysis on the AZ31 Magnesium alloy using neutron diffraction method <i>T H Priyanto, A Insani, R Muslih, and Bharoto</i>	297
Analysis of external radiation exposure from building materials using resrad-build (case study: Perumnas Bumi Guwosari) <i>D F Anggraeni, G S Wijaya, and A Muharini</i>	298
Design of sorting machine prototype in electronic circuit based on NI-MyRIO 1900 <i>N Kurniawati, Adi Abimanyu, and Muhtadan</i>	299
Construction of digital survey meter model SDM-03 using ATMega 8 microcontroller <i>Jumari, N Supriyanto, H Aditesna, and S Widodo</i>	300
Design of power control system for automatic operation of the Kartini reactor <i>Sutanto, F R Iskandar, and P I Wahyono</i>	301
Determination of micro essential element Fe in foodstuffs using instrumental neutron activation analysis (INAA) <i>S Yusuf, S Suprpti, Istanto, R Mulyaningsih, Sutisna, and Alfian</i>	302
Design of control instrumentation system for setting the stripper position on DECY-13 cyclotron <i>Saminto, A Susanto, R Fajarudin, A Budianto and A Abimanyu</i>	303
Design of the controller module of mobile carrier radioactive source <i>D F Atmoko, J Triyanto, M Amin H D, F Harahap, and T Jayadiharja</i>	304
Design of reflector TRIGA mark II Bandung waste container shielding using micro shield 7.02 <i>Irsyad, S Purnomo, and R H Oetami</i>	305
Study using internet of things to control radiation level <i>A Taufiq and S Zanuvar</i>	306
Characterization of wood-borax composites as alternative neutron shielding material using neutron radiography techniques <i>A S Afrozi, A Rachminisari, R Salam, and A Nana S</i>	307
In-situ battery measurement of LiFePO <sub>4</sub> cathode during charge mechanism using X-ray diffraction <i>E Hutamaningtyas, Sudaryanto, B Sugeng, W Honggowiranto, and E Kartini</i>	308
Assessment of heavy metals concentration in the water around the area of Adipala Cilacap steam power plant using neutron activation analysis <i>K Rozana, Sukirno, D S Prabasiwi, and S Murniasih</i>	309
Initial optimization of fine tuner's position on the cyclotron DECY-13's RF dee system <i>R S Darmawan, K Wibowo, and F I Diah</i>	310
Correction of vertical point of projection images using the correct axis tilt parameter in the Octopus software package <i>F Suryaningsih and D C Dewi</i>	311
Determination of internal and external hazard index of natural radioactivity in well water samples <i>D S Purnama and T Damayanti</i>	312
Steady-state thermal-hydraulic analysis of the TRIGA 2000 reactor core when using configuration of 105 fuels <i>R Nazar and J S Pane</i>	313
Determination of radioactivity discharge limit to the atmosphere on Bandung nuclear area <i>J Chussetijowati and H Seno</i>	314

Design of rotating table control for acquiring an image in industrial gamma-ray CT prototype using Raspberry Pi 3B+ module <i>I Shobari, R T Saputra, D Handoyo, and D A Rahadi</i>	315
Application of Thomas Fermi model on the study of the transition phase from the inner crust to the core of neutron star <i>I Lathifa and E T Sulistyani</i>	316
Estimation of air cooling requirement for the Soebali 2.0 laboratory <i>Sutadi, Saefurrochman, E Nuraini, and Suprpto</i>	317
Analysis of coolant flow distribution to the reactor core of modified TRIGA Bandung with plate-type fuel <i>V I S Wardhani, J S Pane, and S Dibyo</i>	318
Synthesis and characterization of hydroxyapatite from duck eggshell modified silver by gamma radiolysis method <i>F Nurfiana, A Kadarwati, and S Putra</i>	319
Design of gamma irradiator simulator category IV using Arduino Mega's <i>I A Purbhadi, B Suhendro, and D S Ayudya</i>	320
Radiation shielding design requirement in the proton energy measurement facility at DECY-13 cyclotron <i>Silakhuddin, Suharni, and K Wibowo</i>	321
Gas flow control design vapor deposition in chemical facilities <i>T Dermawan, N P Priambogo, and S Rianto</i>	322
Analysis of heat transfer at electron beam machine 300 kV/20 mA laboratory <i>L Arifudin, Saefurrochman, Suprpto, and Sutadi</i>	323
Magnetic field of DECY-13 from numerical extrapolation of the measurement result for beam trajectory simulations in central region <i>I A Kudus, Silakhuddin, P Anggraita, and M Satriawan</i>	324
Development of PID-based furnace temperature control system for zirconium calcination <i>E W Febriardy, Sutanto, and A Abimanyu</i>	325
Application of nuclear analytical techniques to assess air quality in Indonesia <i>M Santoso, D D Lestiani, S Kurniawati, E Damastuti, and J Osan</i>	326
Simulation study for ion beam extraction of 150 keV/2mA ion implantor by using SIMION 8.1 <i>S R Adabiah, Saefurrochman, S Munawaroh, and S R Haniah</i>	327
Testing and evaluation of velocity selector control system of small angle neutron scattering spectrometer <i>N Suparno, Bharoto, and A Patriati</i>	328
Development of drone mounted aerial gamma monitoring system for environmental radionuclide surveillance in BATAN <i>S Widodo, A Abimanyu, and R Apribra</i>	329
Automation of mixing tank system in STTN-BATAN mini plant using DCS Centum VP <i>Y Irwanto, D Harsono, and Sutanto</i>	330
Visualization of dose distribution inside soft X-ray machine based on OSL technology <i>N Nagara</i>	331
Three axis milling machine applications for welding samples test neutron instrument using friction stir welding method <i>M Saparudin, T H Priyanto, R Apriansyah, and R Muslih</i>	332

Performance analysis of digital X-ray radiography system in radiometallurgy installations for pebble bed fuel imaging	333
<i>S Ismarwanti, H F Rahmatullah, R Artika, R Sigit, M K Ajiriyanto, and J Setiawan</i>	
Neutronic analysis of comparison UN-PuN fuel and ThN fuel for 300 MWth Gas Cooled Fast Reactor long life without refueling	334
<i>R D Syarifah, A Arkundato, D Irwanto, and Z Su'ud</i>	
Transfer factor as indicator of heavy metal content in plants around Adipala steam power plant	335
<i>D S Prabasiwi, Sukirno, S Murniasih, and K Rozana</i>	
Characterization of suspended PM 2.5 and PM 10 concentration and radioactivity around Rembang steam power plant	336
<i>Sukirno, S Murniasih, and D S Prabasiwi</i>	
Real-time acquisition and correction of temperature effect in NaI(Tl) detector-based environmental gamma radiation detection device	337
<i>I P Susila, Istofa, Sukandar, and B Santoso</i>	
Applicability of EDXRF for elemental analysis in airborne particulate matter (APM): assessment using APM reference material	338
<i>D K Sari, D D Lestiani, S Kurniawati, N Adventini, D P D Atmodjo, and I Kusmartini</i>	
An interlaboratory comparison of INAA analytical method for coal fly ash elemental characterization	339
<i>E Damastuti, M Santoso, S Yusuf, and Y N S Woro</i>	
Assessment of natural radioactivity levels in soil sample from Botteng Utara Village, Mamuju Regency Indonesia	340
<i>Nurokhim, Kusdiana, and E Pudjadi</i>	
Determination of TRIGA 2000 reactor parameters for NAA absolute methods	341
<i>S Kurniawati, D P D Atmodjo, N Adventini, I Kusmartini, W Y N Syahfitri, D K Sari, E Damastuti, D D Lestiani, and M Santoso</i>	
Characterization ionic species fine particulate samples in Indonesia by ion chromatography	342
<i>I Kusmartini, N Adventini, S Kurniawati, D D Lestiani, E Damastuti, and D K Sari</i>	
River water classification pattern in Malang city based on electronic tongue for identification of environmental pollution	343
<i>I Tazi, S N Margareta, W Y Setyandita, H Muttamaqin, S K Kulliyana, A Muhaimin, and Muthmainnah</i>	
Neutron activation analysis of natural dyes elements to minimize batik industry wastewater	344
<i>L Indrayani, M Triwiswara, IR Salma, and E Nuraini</i>	
Analysis of heat and mass transfer on cooling tower fill	345
<i>A A R Hakim and E A Kosasih</i>	
Verification of the output determination of 12 MeV electron beam from an elekta versa HD/154714 linear accelerator machine at Mayapada hospital	346
<i>A F Firmansyah, O A Firmansyah, and Y S Asril</i>	
An analysis of radiation worker safety at SAMOP facility PSTA-BATAN Yogyakarta using MCNP6	347
<i>R Riyadi, Suharyana, F Anwar, Riyatun, and Soeparmi</i>	
Modifikasi sistem iradiasi rabbit hidrolis reaktor serba guna G.A. Siwabessy (RSG-GAS) berbasis OPC server dan labview	348
<i>R Gusman, Sujarwono, dan A Abimanyu</i>	

Ambient dose measurement from high natural background radiation (HNBR) in Botteng Utara Village, Mamuju - Indonesia <i>S N Shilfa, B Y E B Jumpeno, Nurokhim, and Kusdiana</i>	367
Design of gamma imaging system for small organs <i>W B Santoso, B Santoso, Sukandar, and L Yuniarsari</i>	368
Growth of ZnS:Ag:Cu thin film deposited on glass substrates using thermal evaporation technique for alpha-photovoltaic <i>E Mulyani, T Sujitno, D Purbandari, Ferdiansjah, and Sayono</i>	374
Validation of [ <sup>99m</sup> Tc]Tc-DTPA radiochemical testing method using one-system paper chromatography <i>A R Putra, E Lestary, Maskur, and Y Tahyan</i>	375
Study of microstructural and corrosion properties of aluminium alloy 7075 after plasma nitriding <i>H Ahmadi, R A Aziz, Suprpto, T Sujitno, and S Hapsari</i>	376
The effect of the gas mixture ratio on 316L stainless steel biomaterial's mechanical properties and crystal structures using DC sputtering technique <i>W Andriyanti, B Arsyad, Ravendianto, T Sujitno, Suprpto, and D Priyantoro</i>	377
Isotherm, thermodynamic, and kinetics studies of iodide adsorption on the Al_SBA-16 mesoporous nanomaterial as radiopharmaceutical vehicle candidate <i>M C Prihatiningsih, S S Retnoasih, A E Andjioe, N A Kundari, and E G R Putra</i>	378
Functional test of electron beam extraction for pulse electron irradiator <i>I Aziz and B Siswanto</i>	379
Characterization of porosity inside limestone as a reservoir of oil using neutron tomography <i>B Bharoto, A Ramadhani, F Akbar, S G Sukaryo, T H Priyanto, M Kurniati, and F A Fadhila</i>	380
Synthesis TiO <sub>2</sub> -Ag thin film by DC sputtering method for dye degradation <i>W Andriyanti, F Nurfiiana, A N Sari, N A Kundari, and I Aziz</i>	381
Applied strain effect to the luminosity and divergence of neutron monochromator with fully asymmetric diffraction <i>M R Muslih, R Apriansyah, and Mikula</i>	382
Effect of drought stress on morphological, anatomical, and physiological characteristics of cempo ireng cultivar mutant rice ( <i>oryza sativa l.</i> ) strain 51 irradiated by gamma-ray <i>Y S Patmi, A Pitoyo, Solichatun, and Sutarno</i>	383
Synthesis of bio-polymer based chitosan and starch with methyl orange dyes as a material potential for low dose gamma film dosimeter <i>D Ariyanti and W Saputri</i>	384
Yield stability analysis of rice mutant lines using AMMI method <i>S Rahayu</i>	385
Analysis distribution of <sup>32</sup> P radioisotope in silicone patch using autoradiography scanner <i>W Y Rahman, E Sarmini, and A Pujiyanto</i>	386
Preparation of bio-composite hydrogel of hydroxyapatite based using gamma irradiation for artificial bone <i>B Abbas, D P Perkasa, Erizal, and F Lukitowati</i>	387
Preparation and characterization of collagen-ciprofloxacin HCL membranes produced using gamma irradiation as a candidate for wound dressing <i>F Lukitowati, B Abbas, Erizal, I W Redja, and H A Febryani</i>	388

Neutron tomography study of a lithium-ion coin battery <i>Y Purwamargapratala, Sudaryanto, and F Akbar</i>	389
The effect of chitosan radiation of spinach plant based on agronomy characteristics on hydroponics floating system <i>A K Dewi, D Z Z Aulya, and E Suryadi</i>	390
Neutron diffraction and the residual stress distribution of magnesium processed by equal channel angular pressing <i>M Rifai, Mujamilah, M R Muslich, Ridwan, M M Sarr, and H Miyamoto</i>	391
Investigation on neutronic properties of ZrC coated advanced TRISO fuel for high-temperature gas-cooled reactors <i>F Aziz, M Panitra, A K Rivai, M Silalahi, N Sabrina, M Dani, M B Setiawan, and T Setiadipura</i>	392
Self-diffusion coefficient of Fe, Pb, Ni and Cr by molecular dynamics simulation using the potential morse <i>L Ma'nun, A Arkundato, Misto, E Purwandari, and Sujito</i>	393
Improvement of bioethanol production in cornstalk fermentation through hydrolysis by fungi <i>Trichoderma reesei</i> exposed to gamma rays <i>N Mulyana, Tri R D Larasati, S Nurbayti, and Q A'yuni</i>	394
Design of low-flow oxygen monitor and control system for respiration and SpO <sub>2</sub> rates optimization <i>A J Puspitasari, D Famella, M S Ridwan, and M Khoiri</i>	395
Elemental analysis of SRM 1547 peach leaves, 1573a tomato leaves, and 1570a spinach leaves <i>Alfian, S Yusuf, and Sutisna</i>	396
Iodine analysis of foodstuffs samples using epithermal instrumental neutron activation analysis <i>Sutisna, S Yusuf, and S Suprapti</i>	397
Preliminary study of scandium-46 labeled composite (hydroxyapatite - chitosan - collagen) biodistribution in rats bone implant model <i>A A Kurniawan, M B Febrian, Iswahyudi, I Daruwati, R J Sugiharti, Y Setiadi, D Darwis, B Abbas, F Lukitowati, and Y Warastuti</i>	398
Study of PMMA dosimeters response against storage temperature and post-irradiation time <i>R Fitriana and M A E Putri</i>	399
Synthesis and characterization of high chromium zirconiaoxide dispersion strengthened (ODS) steel <i>M Silalahi, B Bandriyana, S Ahda, B Sugeng, and A Dimiyati</i>	400
Hydroxyapatite (HA) labeling with a phosphorus-32 radioisotope of the TRIGA 2000 reactor irradiation result as a candidate for radiosinovectomy therapy <i>B S Rattyananda, M B Febrian, Y Setiadi, D Setiawan, A Aziz, T S Mulyati, and A Suherman</i>	401
Pharmacokinetics interaction study of <sup>99m</sup> Tc-glutathione radiopharmaceutical with doxorubicin in mice ( <i>Mus musculus</i> ) <i>T H A Wibawa, A Kurniawan, Iswahyudi, and I Daruwati</i>	402
Synthesis and characterization of magnetite (Fe <sub>3</sub> O <sub>4</sub> ) via radiolytic reduction method <i>F Alawiyah, Muflikhah, W Z Lubis, G T Sulungbudi, Mujamilah, and E G R Putra</i>	403

Optimization of the extraction process in the synthesis of high specific activity Molybdenum-99 by Szilard Chalmers reaction <i>M B Febrian, F N Fadhillah, and M Agha</i>	404
Synthesis and characterization of zeolite-g-polyacrylamide (Zeolite-g-PAAM) by using simultaneous irradiation technique <i>T Puspitasari, D Darwis, D S Pangerteni, O Oktaviani, and M P Sari</i>	405
The synthesis and characterization of rare-earth hydroxide as a processed result of monazite sand <i>Samin, K Setiawan, M Anggraini, and S T Sunanti</i>	406
Design of irradiation facilities at grid E-1 of plate type research reactor Bandung <i>E S Bahrum, H Wibowo, Y Setiadi, W Handiaga, P Basuki, A Maulana, and M B Febrian</i>	407
Analysis of nitrogen ion implantation on the corrosion resistance and mechanical properties of aluminum alloy 7075 <i>S Hapsari, T Sujitno, H Ahmadi, Suprpto, and R A Aziz</i>	408
Synthesis of reduced graphene oxide modified Cu (rGO-Cu) by gamma irradiation and its electroactive properties <i>F Nurfiiana, Giyatmi, and N Anggita</i>	409
Growth of TiN thin film on Al 5083 deposited using dc sputtering technique for improving their hardness and corrosion resistance <i>M A Gifari, W Andriyanti, A Haerul, and M I Rasyidi</i>	410
Labeled of irradiated chitosan with Iodine-131 radioisotope <i>E M Widyasari, M E Sriyani, R J Sugiharti, I Daruwati, B Abbas, D S Pangerteni, and D Darwis</i>	411
Analysis of neutron absorption from NBR rubber type without and with Gd and B <sub>4</sub> C fillers <i>Juliyani, Setiawan, I Sumirat, GS Sulistioso, and A Mahendra</i>	412
Preparation of bacterial cellulose-based adsorbent by simultaneous irradiation method: synthesis and characterization <i>Oktaviani, T Puspitasari, D S Pangerteni, I Indriyati, and A L Yunus</i>	413
The effect of argon:oxygen gas ratio on the energy gap of nickel-chromium oxide thin film deposited using DC sputtering techniques <i>T U Agista, I Aziz, B Pribadi, and D Priyantoro</i>	414
Synthesis and characterization of photocatalist TiO <sub>2</sub> doped with Ni for treatment of waste model from nuclear facility <i>A Rachminisari, A Salim, A Nana, and A Dimiyati</i>	415
Physico-chemical characterization of the Terbium-161 radioisotope through separation based on cartridge LN resin column from irradiated of enriched Gd <sub>2</sub> O <sub>3</sub> target <i>A Aziz</i>	416
Charge ordering at low temperature in lithium manganese oxide spinel <i>T Y S Panca Putra, M Yonemur, S Torii, and T Kamiyama</i>	417
Blood pressure monitoring system: real time-continuous and noninvasive-electronic, based on magnetic dipole moment of the proton spin of hydrogen atoms in the blood <i>B M E Jati, A B S Utomo, G Maruto, and Y R Utomo</i>	418
Neutronic analysis of critical assembly for moly-99 production reactor based on mixed Th-U fuels <i>B Delphito and Syarip</i>	419

Corrosion analysis of post-heat treatment and post-weld SS316 with electrokinetic reactivation and cyclic polarization method	420
<i>M Kartaman A, E Nurlaely, A S D Putri, J Cs Sihotan, and N A Kundari</i>	
Multiband electromagnetic wave absorption study on nanocrystalline (1-x)NiFe <sub>2</sub> O <sub>4</sub> /(x)BaTiO <sub>3</sub> composites	421
<i>E Sukirman, Y Sarwanto, S Ahda, Y Taryana, and S Purwanto</i>	
Synthesis of zirconium oxychloride and zirconia low TENORM by zircon sand from Landak West Kalimantan	422
<i>H Poernomo, Sajima, and N D Pusporini</i>	
Tuning localized surface plasmon resonance (LSPR) of Au-Ag nanoalloys by femtosecond laser	423
<i>A N Hidayah and Y Herbani</i>	
Transfer factor of radiocesium from soil to spinach plant ( <i>Amaranthus sp</i> )	424
<i>P Sukmabuana, I G Pranawiditia, R Tursinah, and J Chussetijowati</i>	
Morphology study of SPIONs coated apoferritin using small-angle neutron/X-ray scattering and transmission electron microscopy	425
<i>A Patriati, W Z Lubis, N Suparno, S Soontaranoon, and Mujamilah</i>	
Development of single sphere spectrometer with gold foil detector for neutron spectrometry	426
<i>Rasito and Bunawas</i>	
X-ray diffraction (XRD) profile analysis of pure ECAP-annealing Nickel samples	427
<i>A D Prasetya, M Rifai, Mujamilah, and H Miyamoto</i>	
Nitrate reductase activity of black rice ( <i>oryza sativa l.</i> ) cempo ireng cultivar strain 13 and 46 as the result of plant breeding using <sup>60</sup> Co gamma ray on drought stress variation	428
<i>V P Putra, Solichatun, Sugiyarto, and Sutarno</i>	
Somatic embryogenesis on irradiated callus of garlic ( <i>Allium Sativum L.</i> )	429
<i>M Y Maryono</i>	
Starch, amylose and amylopectin levels of M5 and M6 generations of black rice irradiated by gamma <sup>60</sup> Co ray	430
<i>R P Bachtari, S Listyawati, and Sutarno</i>	
Preliminary study of iodine analysis in food using epithermal method of neutron activation analysis in TRIGA 2000 reactor pneumatic system facility	431
<i>W Y N Syahfitri, D D Lestiani, N Adventini, D P D Atmodjo, I Kusmartini, D K Sari, S Kurniawati, E Damastuti, and M Santoso</i>	
Preparation and optimization of SBA-16-Al nanomaterials labeled Technetium-99m for radiation imaging applications	432
<i>W Nuraeni, E G R Putra, I Daruwati, and M C Prihatiningsih</i>	
The adsorption isotherm and thermodynamic studies of rhenium onto mesoporous silica nanoparticles	433
<i>M C Prihatiningsih, K T Basuki, P Brawijaya, and A Saputra</i>	
Separation the zircon mineral from tailing TiN mining using shaking table	434
<i>Sajima, T Handini, Suyanti, and Sudaryadi</i>	
Processing and refining of TiN tailing mining	435
<i>N D Pusporini, Suyanti, R A Amiliana, and H Poernomo</i>	
Effect of Gd substitution on the crystal structure, magnetic susceptibility and biocompatibility of nano-sized Ca <sub>10-x</sub> Gd <sub>x</sub> (PO <sub>4</sub> ) <sub>6</sub> (OH) <sub>2</sub> particles	436
<i>Y A Hariyanto, Hartatiek, and A taufiq</i>	



Hierarchical structure and antibacterial activity of olive oil based $MZFe_2O_4$ ferrofluids <i>D Yuliantika, A Taufiq, and E G R Putra</i>	437
Plants covering influence to the radioisotopes existence of $^{137}Cs$ and $^{210}Pb$ in the soil <i>N Suhartini, B Aliyanta, and A Adhari</i>	438
Evaluation of safeguards system implementation in The Center for Applied Nuclear Science and Technology of BATAN for 2013 to 2019 <i>N Ratnaningsih, Nailatussaadah, and A Mediawan</i>	439
An assessment of instructor quality in the BATAN management system assistance program using the likert scale <i>Sunarto, A R Kumaraningrum, Sarju, and Iswanto</i>	446
Safety analysis of the irradiation of Tellurium (Te) target in G.A. Siwabessy reactor <i>Sutrisno, A A R Hakim, and Purwadi</i>	451
Study of the requirements for external expert recruitment by nuclear energy regulatory agency (BAPETEN) <i>L Y Pandi</i>	452
Legal protection for malpractice patients of therapeutic transactions in nuclear medicine facilities <i>S Hadiyantina, K Hadiwinata, and N Ramadhan</i>	459
Study on the implementation of radiation portal monitor certification in Indonesia <i>H Subekti and E Kunarsih</i>	469
The concept of smart classroom for nuclear technology training courses in BATAN <i>Bagiyono</i>	478
Analysis of quality assurance of Irradiator Gamma Merah Putih products using dosing mapping method <i>B Saputro, A Rachmanto, and F H Setiawan</i>	488
Preliminary study of general safety requirements part 2 as a scope for BATAN integrated management system <i>B Saputro, A T Kusuma, Mujiono, and T S Sugiono</i>	499
The implementation of NKM in BATAN: the current status and challenges <i>Sutrasno</i>	508
Review of the management system integration scheme at CANST Bandung <i>Y Kurniati, Khasairin, and R Ekaputra</i>	515
Safety culture survey based on BATAN regulation No. 200/KA/X/2012 from 2014 to 2018 at multi purpose reactor (PRSG) <i>W Prasud, H Unggul, and S Slamet</i>	529
Utilization of IAEA e-learning course on neutron activation analysis for education and training purposes <i>Y T Handayani and Indragini</i>	536
Strengthening radiography personnel certification LSP – BATAN through the role of quality assurance based on SNI ISO - IEC 17024: 2012 <i>B Hanurajie, R L Tyas, and B Santoso</i>	545
Building leadership competence for nuclear safety <i>R Alamsyah</i>	550
Standardization of security risk assessment in nuclear area <i>A B Purnomo, Sugiyarto and I H Purnomo</i>	558

SNI development: RSG-GAS as working standard of national research reactor temperature measurement	563
<i>E P Hastuti, A B Purnomo, M Ayundiahrini, S L B Butar, Sudarmono, Sujarwono, H Suherkiman, and R Gusman</i>	
Validation of personal certification through examination analysis	573
<i>Siswoto, R L Tyas, A Meliana, and J Susanto</i>	
The implementation of risk-based thinking based on ISO/IEC 17025 for the auditor at the Center for Nuclear Standardization and Quality, National Nuclear Energy Agency of Indonesia	579
<i>D Listianti, Muhidin, Agus, and R L Tyas</i>	
Study on knowledge management system in Indonesian Nuclear Energy Regulatory Agency (BAPETEN)	584
<i>H Haditjahyono, L Hakim, and E Fitriyanti</i>	
Safety study of topaz irradiation management at the in core RSG-GAS Position	594
<i>E Sihombing and W Prasud</i>	
Review of radiochemistry capacity building program in Indonesia	595
<i>Indragini and Y T Handayani</i>	
Gamma radiation exposure profile based on the power variation of GA Siwabessy multipurpose reactor in accordance with the extension of operation license	603
<i>Subiharto, N Kurniawan, and P Ramadania</i>	
Improving the quality of nuclear process/product by creating Batan standards for certification of nuclear process/product design competencies	613
<i>D Intaningrum, R L Tyas, A Meliana, and J Sutanto</i>	
Standardization of calibration for temperature measurement in high-temperature nuclear reactor	620
<i>A B Purnomo, E P Astuti, S L Butar – Butar, and M Ayundyahrini</i>	
Managerial aspects of Nuclear Knowledge Management (NKM) in National Nuclear Energy Agency of Indonesia	624
<i>J Sutanto, A B Purnomo, and P Sulisworo</i>	
A study on radiation dose estimation of Argon-41 and Nitrogen-16 airborne released from Kartini research reactor	636
<i>M Salam and E Suprihati</i>	
Evaluasi operasional dosimetri dalam fasilitas Iradiator Gamma Merah Putih untuk radiasi bahan	637
<i>P Sulisworo, J Sutanto, dan S Darmawati</i>	
Formulation of technical competency dictionary for nuclear technology human resources	645
<i>Bagiyono</i>	
Safety radiation of sealed radioactive sources	656
<i>M A Rahmadani, K Khotimah, A Meliana, and J Sutanto</i>	
Basic design of Indonesia Nuclear Capacity Building for developing countries	660
<i>S Ariyanto</i>	
Licensing preparation for modification of Bandung TRIGA 2000 reactor utilize MTR type fuel 2000 reactor utilize MTR type fuel	670
<i>E Nurlia and J S Pane</i>	

Radiological safety assessment for recycle of contaminated scrap metal for building materials <i>M Romli, Mahmudin, T S H Nugroho, and W E Reputri</i>	683
Pengembangan sumber daya manusia berbasis kompetensi sebagai upaya meminimalkan kecelakaan kerja di PSTBM-BATAN <i>Suyanto, S Zanuvar, dan A Dimiyati</i>	690
Development of online database application for optimized laboratory equipment information system in the Center for Sciences and Technology of Advanced Materials (PSTBM) <i>A H Handayani, A Sunardi, and A Dimiyati</i>	698
Preparation of personnel certification body (LSP) BATAN to implement the digital radiography qualification and certification personnel <i>Siswoto, B Hanurajie, D Intanningrum, and Umar</i>	707
The reability of data acquisition transfer on Kartini internet reactor laboratory <i>I Riyadi, U S Hidayat, T N H Susanto, N N N Aufani, and R Satria</i>	713
Accreditation of BATAN person certification body (LSP BATAN) scope of certification level 3 radiographers and nuclear engineering and application personnel to increase user trust <i>Siswoto, Sutardi, and F Nurfuadia</i>	720
Study on the effectiveness of the implementation of nuclear knowledge management through e-repositories <i>K Khotimah, R N Cahyani, A R Yusuf, and A Sungkono</i>	728
The current status of the internet reactor laboratory Kartini research reactor for distance learning especially for higher education <i>Taxwim, U S Hidayat, T H Susanto, M Subchan, E Sugianto, A F Anugerah, N Aufani, Z Baskoro, R Satria, and W Karsono</i>	733
Probability study of an airplane crash on the Kartini reactor site area <i>Z E Bhagaskara and N N Aufanni</i>	734
Evaluation of the officer's behavior in public services of nuclear minerals technology <i>N Madyaningarum and I H Pratama</i>	735
Kajian kegiatan litbang iptek nuklir untuk penetapan aspek penting lingkungan <i>Widjanarko, H Yasmine, dan A Ratih</i>	736
Kajian pengembangan laboratorium hewan terstandar biosafety level (BSL) di Badan Tenaga Nuklir Nasional(BATAN) <i>M V Sukarta dan R A Abiyi</i>	743
Kajian evaluasi rencana strategis BATAN 2015-2019 dalam rangka penyusunan kebijakan rencana strategis BATAN 2020-2024 <i>Y Garini dan D Irwanti</i>	759
Perancangan penggunaan data logger pada kualifikasi kinerja autoclave di fasilitas clean room <i>I W Widiana, H Suryanto, Rajiman, dan K Hidayat</i>	767
Analisis hasil penyusunan analisis jabatan di BATAN: studi kasus di Pusat Diseminasi dan Kemitraan (PDK) dan Pusat Kajian Sistem Energi Nuklir (PKSEN) <i>E Kristuti</i>	776
Pembuatan perangkat uji alarm seismik untuk meningkatkan keselamatan operasi reaktor RSG-GAS <i>H Prijanto dan H Suherkiman</i>	791

Simulasi pembuatan aplikasi manajemen sumber radiasi pada Laboratorium Instrumentasi Nuklir Sekolah Tinggi Teknologi Nuklir (STTN)	799
<i>M S Rahman dan H Hamadi</i>	



Indonesia  
Nuclear Expo  
**2019**



# **Determination of the width of gamma radiation field of the OB-85 ( $^{137}\text{Cs}$ source) at calibration facility of PTKMR-BATAN**

**Nazaroh<sup>1,\*</sup>, O A Firmansyah<sup>1</sup>, A F Firmansyah<sup>1</sup>, and A Afham<sup>1</sup>**

<sup>1</sup>Center for Safety and Radiation Metrology Technology – National Nuclear Energy Agency (BATAN), Jl. Lebak Bulus Raya No.49 Jakarta 12440, Indonesia

E-mail: nazaroh\_s@batan.go.id

---

**Abstract.** The OB-85 is one of the main equipments for calibration of Gamma Radiation Measuring Instrument's (RMIs, such as Surveymeter, TLD, pocket dosimeter) at Calibration Facility of PTKMR-BATAN, however, without standard instrument and other supporting tools, the OB-85 will not function properly. To get an accurate calibration result, the width of radiation field of the OB-85, the Air Kerma rate,  $K_a$  [ $\mu\text{Gy/h}$ ], the Ambient Equivalent Dose rate,  $H^*(10)$  [ $\mu\text{Sv/h}$ ], the Personal Equivalent Dose rate,  $H_p(10)$  [ $\mu\text{Sv/h}$ ], the Exposure rate,  $X$  [ $\text{mR/h}$ ], and the expanded uncertainty,  $u_{\text{expand}}$  of these quantities must be measured and determined as they are indispensable for calibration or irradiation of the RMIs. The purpose of determining of the width of radiation field of the OB-85 is to fulfil quality audit of the Calibration Facility, for ascertaining what the actual width of radiation field of the OB-85, belong to the PTKMR-BATAN. At the time of calibration, surveymeter or pocket dosimeter must be placed at the center of radiation field and in the width of radiation field because if it was partially outside of the radiation field then the calibration result was inaccurate. This paper presents the determination of the width of radiation field of the OB-85 by three types of ionization chamber detectors. with different shapes and volumes, with two settings of SDD (Source Detector Distance). The width of radiation field of the OB-85 measured by the IC/SN #M23332, IC/TK-30 #SN107, and IC Exradin/A4 were 18 cm for SDD = 50 cm, and 36 cm for SDD = 100 cm. From this experiment, the information was obtained that the width of radiation field of the OB-85 does not depends on the type of the detectors used to measure but it depends on the calibration facility settings (the shape or geometry of the source, SDD, and diameter of collimator).

---

## **1. Introduction**

The Secondary Calibration Laboratory Network has been set up by the IAEA in many countries, including Indonesia (SSDL-Jakarta). In the beginning, it was set-up standard therapy but gradually with the development of science and knowledge of nuclear engineering, a calibration laboratory for a radiation protection level is also needed.

Regulation of the Head of the Nuclear Energy Supervisory Agency Number 1 of 2006 concerning Dosimetry Laboratory, Radiation Measurement Calibration Instrument and Radiation Source Output, and

Radionuclide, in Article 7 states that the National Level Laboratory (NLL) is responsible for fostering and providing technical guidance to the Secondary Standard Dosimetry Laboratory (SSDL) and the Tertiary Standards Dosimetry Laboratory (TSDL) and in article 10 it is said that for a new of RMIs or after being repaired, the RMIs must be calibrated before used and must be recalibrated every year. This is to ensure that the RMIs works properly, according to its designation and is traced to higher laboratories (national and international) [1,2].

The Gamma Calibration Facility of PTKMR-BATAN which is an IAEA assistance, currently only uses  $^{137}\text{Cs}$  (OB-85) and  $^{241}\text{Am}$  sources for Gamma RMIs calibration. In 1985, there were three sources installed in the Calibration Facility of PTKMR-BATAN namely  $^{226}\text{Ra}$ ,  $^{137}\text{Cs}$ , and  $^{60}\text{Co}$ . At the moment,  $^{60}\text{Co}$  was very low its activity because the half-life of  $^{60}\text{Co}$  was 5.27 years [3], while the shutter for  $^{226}\text{Ra}$  was broken.

$^{137}\text{Cs}$  has a half-life of about 30.17 years, it decays to  $^{137}\text{Ba}$  by emitting 0.6617 MeV of gamma energy, with the decay chart presented in Figure 1a and its Spectrum presented in Figure 1b. Because of its long half life,  $^{137}\text{Cs}$  are widely used for various specific purposes, for example as a Radiation Measuring Instrument (RMIs) calibrator, in the field of medicine, it used for diagnosis and radiation therapy, in the Industry, it is used as a flow meter, for measuring thickness, leveling, and density of fluid [3,4].

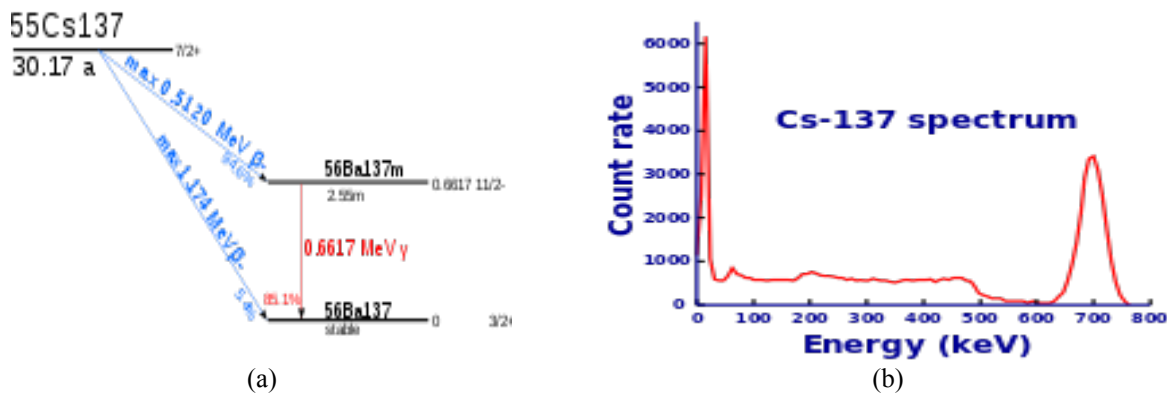
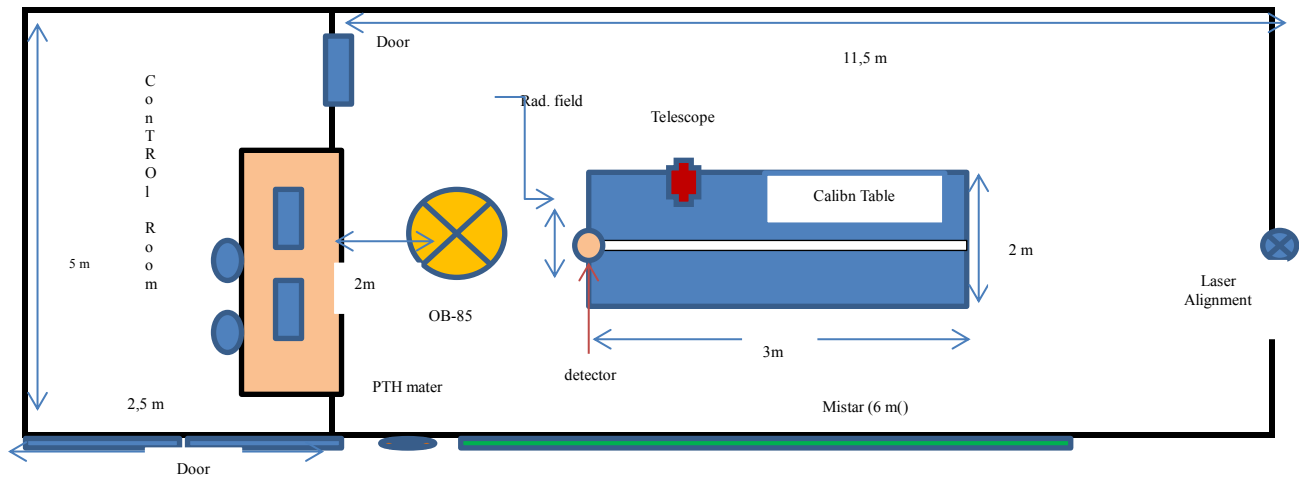


Figure 1. (a) Decay scheme of  $^{137}\text{Cs}$ , (b) Spectrum  $^{137}\text{Cs}$

The  $^{137}\text{Cs}$  source used as the RMIs Calibrator in PTKMR BATAN Calibration Facility is OB-85, made by Buchler GmbH, with the activity was 74 GBq, at Reference Time: May 1985 (Figure 2a). The OB-85 was placed in the middle of the calibration facility, about 2 m from the door. The calibration table can be adjusted from 0.5 m to 4.5 m from the OB-85. Laser alignment was mounted on the wall of the calibration room, about 9.5 m away from the source, facing the source, OB-85. The meter was mounted on the wall to the right of OB-85, with the zero point exactly at the source position. The telescope is mounted on the calibration table, left of OB-85, to adjust Source Detector Distance (SDD) and central of the detector. Pressure, Temperature, and Humidity meter (P, T, H) were mounted on the wall to the right of OB-85. The Calibration Room of PTKMR-BATAN was presented in Figure 2. Calibration/irradiation of the RMIs were controlled from the control room. Room conditions are recorded when taking measurement/calibration data.



**Figure 2.** The Calibration Room of PTKMR-BATAN

For the purposes of Quality Audit of the RMIs Calibration Facility and for the National Accreditation Committee (NAC), the width of the OB-85 source radiation field must be known exactly, as well as the Air Kerma Rate,  $K_a$ , Personal Equivalent Dose Rate,  $H_p(10)$ , Ambient Equivalent Dose Rate,  $H^*(10)$ , and the Exposure Rate,  $X$  at several calibration points because these quantities are needed in the calibration activities. This information is very useful when performing RMIs calibration or TLD irradiation.

In this paper, determination of the width of radiation field of the OB-85 has been done, using 3 types of ionization chamber detectors: Ionization Chamber/SN #M23332, cylindrical shape, volume 0.3 cc, IC/TK-30/SN107, spherical shape, volume  $\pm 30$  cc and Exradin/A4, ball shape, volume 30 cc.

## 2. Method

### 2.1. Detector stability

To do a measurement, the detector must be checked firstly. The detector of IC was connected to electrometer and turned ON and let them  $\pm 30$  minutes to warm up. To check the stability of the instrument, it can be used the available  $^{90}\text{Sr}$  check source. To determine the stability of the detector, a Standard Operational Procedure (SOP) was required, for example, determine the stability of the detector. The stability check is within the range of  $\pm 1\%$ , then we consider that the detector was stable and ready for measurement.

Control Charts should be made every year to see the stability of the detector because this is very important for quality control (QC) and it is needed when there is an assessment from the National Accreditation Committee (NAC). This stability range will contribute to the measurement/calibration uncertainty. For evaluation of QC's detector stability, the equations (1) and (2) can be used.

$$B_t = B_i \cdot e^{-(0.693t)/T} \quad (1)$$

$$\text{Stability} = \frac{B_t - B_i}{B_i} \times 100\% \leq 1\% \quad (2)$$

- $B_t$  : Detector reading of check source at time  $t$
- $B_i$  : Detector Reading of check source in the first time
- $T_{1/2}$  : Half-life of check source,  $T_{1/2} (^{90}\text{Sr}) = 28.7$  years
- $t$  : Time difference between  $B_i$  and  $B_t$



### 2.2. Detector repeatability

Repeatability: is the ability of a measuring instrument to show the same results from a measurement process that is repeated and identical. Repeatability of the detector, can be seen from the results of repeated measurements. Repeatability is the standard deviation of the measurement. If the results of repeated measurements in the range of  $\pm 1\%$ , the repeatability is good. This repeatability will contribute to the measurement/calibration uncertainty.

### 2.3. Determination of the width of the radiation field of the OB-85

To determine the width of radiation field of the OB-85, we should have a Standard Operational Procedure (SOP) for limiting the saturation curve / peak measurement within a certain range, for example  $\pm 2.7\%$ . In that range, we consider it is still within the wide range of the radiation field. To get that range, the measurement results are normalized to the central position. If the reading of the measuring instrument is still in the range of  $\pm 2.7\%$ , then we consider that it was in the range of the width of the radiation field.

After checking the stability and repeatability, the detector -1 can be used to determine the width of radiation field of OB-85. Detector-1 was placed at the central source of OB-85 with SDD 50 cm. The data was taken 5 data at each measurement point. The detector was moved every 2cm to the right, and the data collection is done in the same way, until a significant decrease in reading occurs. Measurements are made to the left of the source's central point, until a significant reading decrease is obtained. Measurements are also made at SDD of 100 cm with the same steps. Determination of the field width of the OB-85 was also carried out using detectors 2 and 3. After obtaining the data, an evaluation was conducted.

### 2.4. Measurement of Air Kerma Rate, $\check{K}_a$ [2]

The air Kerma rate,  $\check{K}_a$  of the OB-85 was measured using calibrated Ionization chamber [5,6], at the reference point along the X-axis of the radiation field. For the calculation of air kerma rate, it can be used equation (3) under standard STP conditions ( $20^\circ$ , 101.3 kPa). If the conditions are not standard, the correction should be done using equation (4).

$$\check{K}_a = M \times N_k \times K_{PT} \quad (3)$$

$$K_{PT} = \frac{1013,25}{P} \times \frac{T+273}{293,15} \quad (4)$$

M : The average reading of a dosimeter/electrometer

$N_k$  : Calibration Factor for the detector [ $\mu\text{Gy} / \text{nC}$ ]

$K_{PT}$  : Pressure and Temperature Correction Factors

### 2.5. Uncertainty in Measurement of Air Kerma Rate [9, 10, 11, 12]

All measurement instruments have an uncertainty value associated with the measurement. This uncertainty can vary from time to time. The measurement results can only be declared true if the value of the measured is provided with a deviation limit from the measurement results. Tolerance or deviation limit is known as uncertainty.

For the calculation of the uncertainty of Air Kerma Rate, the ISO-Guide to the Expression of Uncertainty of Measurement can be used [9, 10, 11, 12]. Basically, measurement uncertainty can be grouped into Type A and Type B. Type A, evaluated by the statistical method while type B is evaluated by other methods, usually Type B uncertainty data comes from the calibration certificate of the equipment used.

The measurement uncertainty related to the Air Kerma Rate,  $\check{K}_a$  is calculated from equation (3).

$$K_a = M \times N_k \times K_{PT} \quad (3)$$

The related parameters used to calculate the combined uncertainty were standard uncertainties of M,  $u_M$  (Type A), standard uncertainties of calibration factor,  $u_{NK}$ , standard Uncertainty of thermometer,  $u_T$  and barometer,  $u_{bar}$ . Standard uncertainty of meter,  $u_m$ ; standard uncertainty of timer,  $u_t$ ; standard uncertainty of distance,  $u_D$ .

The combined uncertainty of Air Kerma Rate was:

$$(u_c)^2 = (c_1 u_1)^2 + (c_2 u_2)^2 + (c_3 u_3)^2 + (c_4 u_4)^2 + (c_5 u_5)^2 + (c_6 u_6)^2 \quad (5)$$

$$(u_c)^2 = (c_M u_M)^2 + (c_{NK} u_{NK})^2 + (c_P u_P)^2 + (c_T u_{CT})^2 + (c_t u_t)^2 + (c_D u_D)^2 \quad (5)$$

$$c_1 = c_M = \frac{\partial K}{\partial M} = \frac{N_k K_P K_T}{M} \quad (6)$$

$$c_2 = c_{NK} = \frac{\partial K}{\partial N_k} = \frac{M K_P K_T}{N_k} \quad (7)$$

$$\text{Pressure Correction Factor} = \frac{1013,25}{P}, \quad c_3 = c_P = \frac{\partial K}{\partial P} = -\frac{1013,25}{P^2} \times K_T \times M \times \frac{N_k}{t} \quad (8)$$

$$\text{Temperature correction factor} = \frac{T+273}{293,15}, \quad \text{so } c_4 = c_T = \frac{\partial K}{\partial T} = \frac{1}{293,15} \times K_P \times M \times \frac{N_k}{t} \quad (9)$$

$$c_5 = c_t = \frac{\partial K}{\partial t} = M \times N_k \times K_P \times \frac{K_T}{t^2} \quad (10)$$

$$c_6 = c_D = \frac{\partial K}{\partial D} = \frac{2}{D^3} \quad (11)$$

Finally,  $u_c$  can be calculated using equation: (5), (6), (7) to ..... (11) and  $u_M$  from measurement (type A),  $u_{NK}$ ,  $u_P$ ,  $u_T$ ,  $u_t$ ,  $u_D$  can be obtained from certificate (type B).

Furthermore, the degree of effective freedom,  $v_{eff}$  is calculated using equation (12)

$$v_{eff} = \frac{u^2(Y)}{\sum \frac{u_i^4}{v_i}} \quad (12)$$

Finally, the expanded uncertainty,  $U_{exp}(\check{K}_a)$  was calculated using equation (13)

$$U_{expanded} \check{K}_a = k \times u_c(\check{K}_a) \quad (13)$$

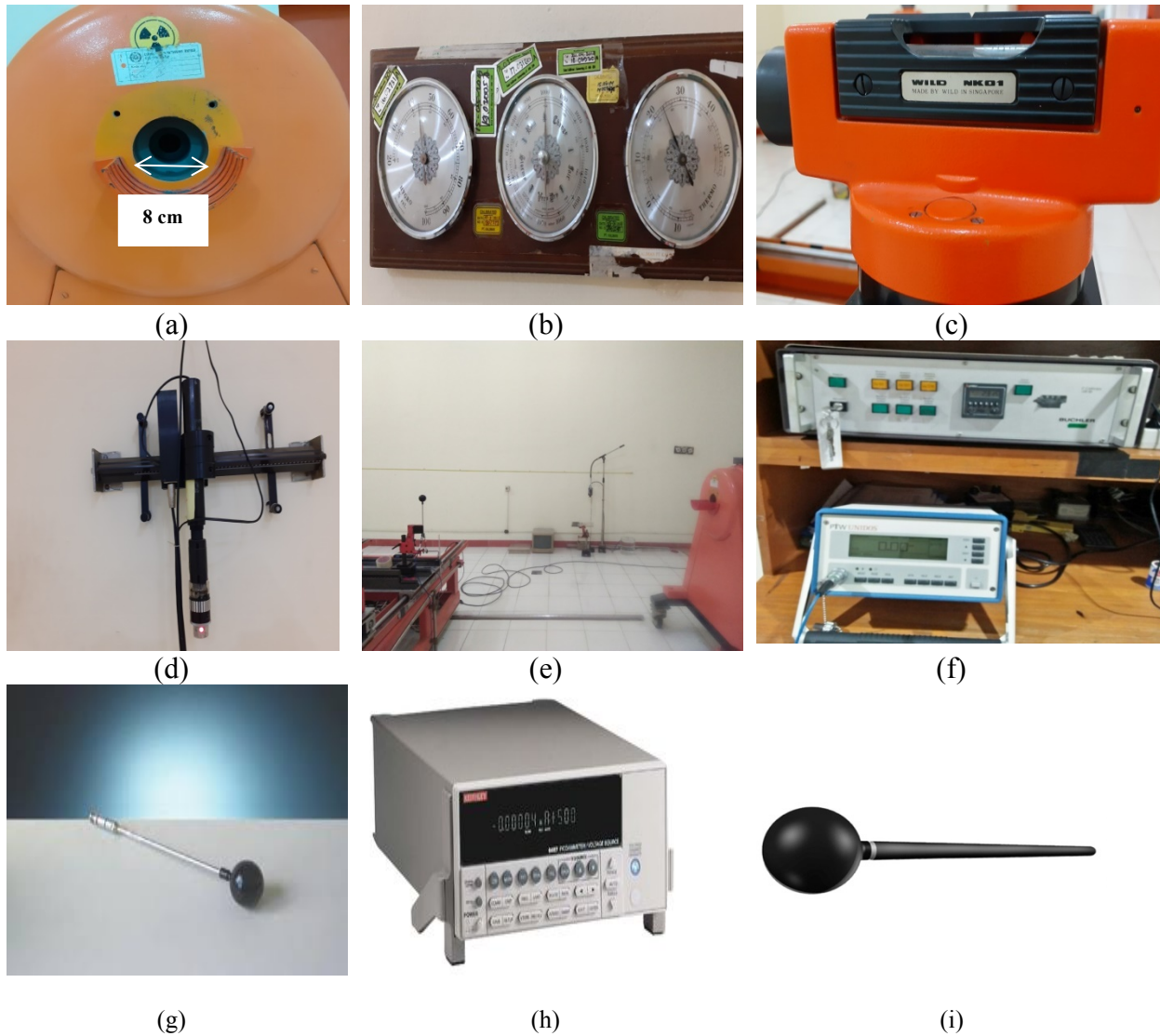
K: coverage factor, k depends on  $v_{eff}$ , use *confidence level* (CL) 95%.

### 3. Working Procedure

#### 3.1. Material and Equipment

- Source  $^{137}\text{Cs}$  (OB-85) made by Buchler GmbH, activity 74 GBq (May 1985), with shielding, collimator, and control panels (shutter and timer)
- Check-source:  $^{90}\text{Sr/No}$ :23261/035 to check detector stability
- IC Detector/M23332/SN #204, volume 0.3 cm<sup>3</sup>, cylindrical and Keithley/PTW Unidos
- IC Detector, Exradin A4, ball, volume 30 cc and electrometer Keithley #6487 (Figure 3i)
- IC Detector TK-30/SN #107, spherical, and PTW Unidos Weblin/T10001/11814
- Calibration table, meter, telescope and laser alignment (Figure 3a)
- Measuring devices (room temperature, pressure, humidity) meter (Figure 3b)

In Figure 3a; 3b; 3c; ..... to 3i are the equipments used to determine the width of radiation field of the OB-85 at Calibration Facility in PTKMR-BATAN.



**Figure 3.** (a)  $^{137}\text{Cs}$  (OB-85) in the shielding and collimator, (b) The device for measuring temperature, pressure and humidity, (c) Telescope for adjusting the detector's position, (d) *Laser alignment* for aligning detector's positions with respect to sources, (e) Setting the measurement of the radiation field width of the OB-85 field, (f) Unidose Weblin PTW, control panel and electrometer, (g) Ionization Chamber Detector TK-30 / SN # 107, (h) electrometer Keithley #6487, and (i) Detector Exradin A4

### 3.2. Detector repeatability

Tables 3. and 4. present the repeatability of the detector in the radiation field measurements at detector positions 0, 2, and 4 cm from the central, at SDD = 50 cm and at the detector position: 0, 4, 8 cm from the central, at SDD 100 cm.

### 3.3. Determination of the width of the radiation field

To find out the width of radiation field of the OB-85 using the three types of Ionization Chamber, the equipment settings as shown in Figure 2e. The detector was placed on a calibration table using stajips, adjusting the height so that the radiation field hits the center of the detector. The detector is placed in front of the source (in the central position) at the Source Detector Distance (SDD) = 50 cm, with the help of laser alignment.

The detector is connected to a Unidose PTW electrometer/Keithley electrometer, depending on the type of detector and its connector. For M23332/SN #204 detector, the working voltage is set at 400 volts. As for the TK-30/SN #107 detector, the working voltage is set at 300 volts. At each detector, the device was heated for 30 minutes to get an electronic balance.

Source  $^{137}\text{Cs}$  (OB-85) is opened by pressing the button on the control panel. Gamma radiation from  $^{137}\text{Cs}$  will travel in the air and hit the Ionization chamber detector. Gamma radiation that interacts with air in the detector, will ionize the air and will produce an ionization current. The ionization current was measured by the Unidos Webline PTW electrometer/Keithley electrometer. From each measurement position, 5 data were taken. The position of the detector is shifted from central to right and left every 2 cm for SDD = 50 cm and 4cm for SDD = 100 cm. Average current data obtained at detector position: 0;  $\pm 2$ ;  $\pm 4$  ...  $\pm 20$  cm (SDD = 50 cm) and the average current data at the detector position: 0; 4; 8 ... 40 cm (SDD = 100 cm), was plotted and presented in Figure 4b; 4c; 4d, and 4e.

### 3.4. Air Kerma Rate, Ambient Equivalent Dose Rate and Exposure Rate

The Table 5. presents the Reference value of OB-85 output (Air Kerma Rate,  $\dot{K}_a$ , Personal Equivalent Dose rate,  $H_p(10)$ , Ambient Equivalent Dose Rate,  $H^*(10)$  and Exposure Rate), X at SDD 50, 100 and 200 cm, with Reference Time: August 7, 2019. This Reference Value is used as a comparison in determining of RMIs Calibration Factor (CF).  $CF = \frac{\text{Reference Value}}{\text{RMI Reading}}$  [IAEA / SRS-16-2000]. Based on the gamma of RMIs calibration SOP, if the CF is in the range of 0,8-1.2, a Calibration Certificate will be issued.

### 3.5. Uncertainty in Measurement of Air Kerma Rate [9,10, 11, 12]

The mathematical equation (3) can be used to calculate the air Kerma rate,  $K_a$ .

$$K_a = M \times N_k \times K_{PT} \quad (3)$$

Mathematical equation (5) can be used to calculate the combined uncertainty of the Air Kerma rate,  $u_c(K_a)$ .

$$u_c^2(K_a) = (c_M u_M)^2 + (c_{N_k} u_{N_k})^2 + (c_{P_u} u_P)^2 + (c_{T_x} u_{CT})^2 + (c_{I_u} u_I)^2 + (c_{D_x} u_D)^2 \quad (5)$$

The degrees of effective freedom,  $\nu_{\text{eff}}$  is calculated by equation (12).

$$\nu_{\text{eff}} = \frac{u^2(\gamma)}{u_i^4 / \nu_i} \quad (12)$$

Finally, the expanded uncertainty,  $U_{\text{exp}}(K_a)$ , can be calculated using equation (13).

$$U_{\text{exp}}(K_a) = k \times u_c(K) \quad (13)$$

k: coverage factor, it depemds on the  $\nu_{\text{eff}}$ , k for confidence level (CL) 95%.

#### 4. Result and Discussion

In Figure 4a, The Schematic for measuring the width of radiation field of OB-85 was set-up. From this schematic, we get the information that the more radiation field will we get if the more diameter of the collimator and the more of SDD (Source Detector Distance).

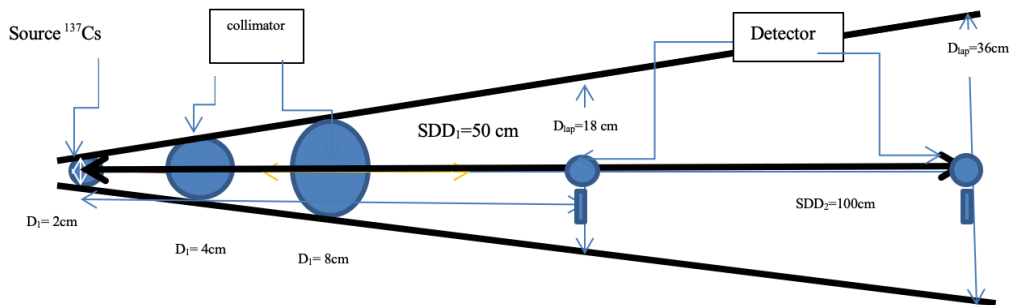
In Figure 4b, 4c and 4d, the width of radiation field of the OB-85 were obtained, they were 18 cm for SDD = 50 cm, and 36 cm for SDD = 100 cm, using the Ionization chamber/SN #M23332, TK-30/SN #IC107 and Exradin A4. The results are a little less symmetrical. This may be because of the position of the source (inside the collimator) slightly to the right. By getting this information, the calibration operator should place calibration object (surveymeter or APD) in this radiation field range. If the RMIs exceeds 18 cm, use SDD more than 50 cm, so the width of radiation field was more than 18 cm. where  $D_1$ ,  $D_2$ ,  $D_3$  are collimators, diameter 1, 2 and 3 are 2, 4, 8 cm, respectively.  $S_1$ ,  $S_2$  are distance of source to collimator 1 and 2 which are 6 and 8 cm.  $SDD_1$ ,  $SDD_2$  are source detector distance 1 and 2 whics are 50 and 100 cm, respectively.

At SDD = 50 cm, the average current measured by the IC detector M23332 was  $(27.99 \pm 2\%)$  pA and at SDD = 100 cm, the average current was  $(7.43 \pm 1.4\%)$  pA, see Table 2 and 3, column 4, at one standard deviation.

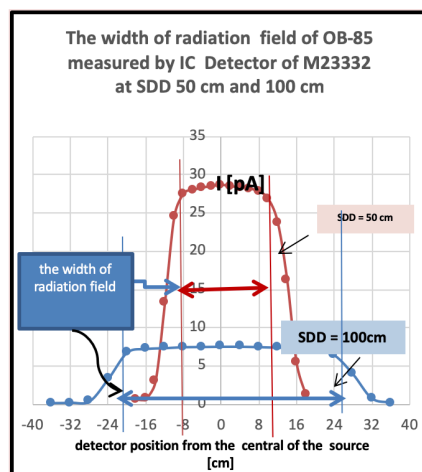
In Figure 4c. at SDD = 50cm, the average current measured by the IC TK-30/SN #107 was  $(24.72 \pm 1.7\%)$  pA, and at SDD 100 cm, the measured current was  $(6.49 \pm 2\%)$  pA, at one standard deviation. In Figure 4d. at SDD = 50cm, the average current measured by the IC Exradin A4 was  $(25.88 \pm 2.7\%)$  pA, and at SDD 100 cm, the measured current was  $(6.76 \pm 2.3\%)$  pA, at one standard deviation.

By using three types of Ionization Chamber detectors, it was obtained that the width of radiation field of the OB-85 was 18 cm and 36 cm, at SDD = 50 cm and 100 cm, See Table 1. The width of radiation field was not depending on the kind of the detector used to be measured but it depends on the geometry of the source, collimator, and SDD (Source Detector Distance) (see Figure 4a).

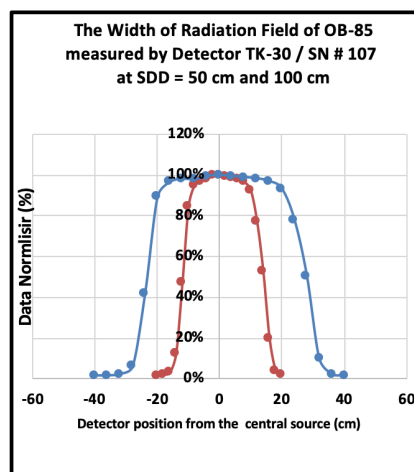
In Figure 4d, at SDD = 50 cm and SDD=100 cm, the width of radiation field of the OB-85 was presented, that are 18 cm and 36 cm, measured by three types of detector. Tables 2 and 3 present the repeatability for the three types of Ionization chamber detectors. The repeatability of the three types of detectors is less than 1%. These data are obtained from measurements of the width of the radiation field at SDD = 50 cm, at the position of the detector (0-4) cm from the source center and (0-8) cm at SDD = 100 cm, the detector's repeatability is quite good/quite small, but it will contribute to uncertainty in the calibration of the radiation gauge.



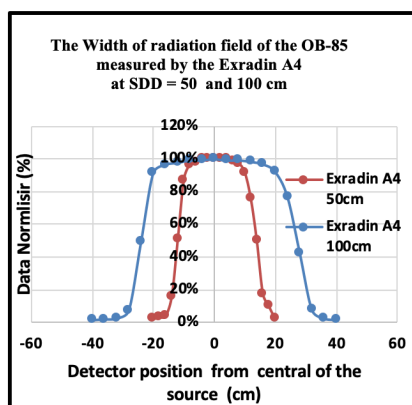
(a)



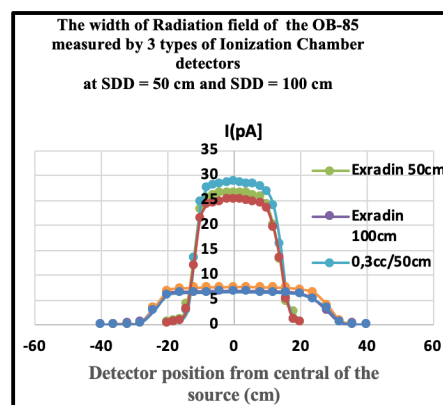
(b)



(c)



(d)



(e)

**Figure 4.** (a) The Schematic for measuring the width of radiation of the OB-85, (b) The width of radiation field of OB-85 measured by IC Ionization chamber of M2333, (c) The Width of Radiation Field of OB-85 measured by IC TK-30/SN #107, (d) The width of radiation field of the OB-85, measured by the Exradin A4, and (e) The width of radiation field of the OB-85 Measured by three types of the detectors

**Table 1.** Radiation Field of the OB-85 measured by three types of ionization chamber detectors and keithley electrometer at SDD 50 and 100 cm

Horizontal position		TK-30/107 [pA]		EXRADIN/A4 [pA]		M23332 [pA]	
SDD=50c m	SDD=100c m	SDD=50c m	SDD=100c m	SDD=50c m	SDD=100c m	SDD=50c m	SDD=100c m
-8	-16	24.00	6.40	25.42	6.67	27.51	7.23
-6	-12	24.41	6.50	25.87	6.76	27.97	7.35
-4	-8	24.73	6.49	26.32	6.85	28.28	7.47
-2	-4	25.16	6.60	26.34	6.86	28.47	7.5
0	0	25.20	6.63	26.36	6.91	28.63	7.53
2	4	25.06	6.60	26.35	6.85	28.46	7.53
4	8	24.92	6.56	26.35	6.86	28.31	7.48
6	12	24.68	6.52	25.98	6.80	28.16	7.41
8	16	24.33	6.43	25.60	6.69	27.78	7.34
10	20	23.30	6.18	24.18	6.37	26.80	7.05
Average =		<b>24.72</b>	<b>6.49</b>	<b>25.88</b>	<b>6.76</b>	<b>27.99</b>	<b>7.43</b>
Stdev =		<b>0.41</b>	<b>0.13</b>	<b>0.69</b>	<b>0.16</b>	<b>0.56</b>	<b>0.10</b>
Stdev (%) =		<b>1.7</b>	<b>2.0</b>	<b>2.7</b>	<b>2.3</b>	<b>2.0</b>	<b>1.4</b>
<b>The width of radiation field of OB-85</b>		<b>18 cm</b>	<b>36 cm</b>	<b>18 cm</b>	<b>36 cm</b>	<b>18 cm</b>	<b>36 cm</b>

**Table 2.** The Repeatability of three types of ionization chambers for current measurement of the OB-85 in the range of radiation field of (0-8) cm, at SDD = 100 cm

Detector position (cm)	I(EXRADIN/A4) pA			I(TK-30//SN#107) pA			I (M-23332/0,3 cc) pA		
	0	4	8	0	4	8	0	4	8
	6.89	6.87	6.86	6.60	6.60	6.55	7.55	7.55	7.50
	6.90	6.86	6.86	6.60	6.50	6.50	7.55	7.55	7.45
	6.91	6.85	6.85	6.65	6.55	6.60	7.50	7.50	7.45
	6.92	6.84	6.86	6.60	6.60	6.55	7.50	7.50	7.50
	6.92	6.84	6.86	6.70	6.65	6.60	7.55	7.55	7.50
Average	6.91	6.85	6.86	6.63	6.60	6.56	7.53	7.53	7.48
Stdev (%)	0.46	0.14	0.48	0.63	0.41	0.42	0.36	0.36	0.37
Repeatability	Good (below 1%)			Good (below 1%)			Good (below 1%)		

**Table 3.** The Repeatability of three types of ionization chambers for current measurement of the OB-85 in the range of radiation field of (0-4) cm, at SDD = 50 cm

Detector Position (cm)	EXRADIN/A4			TK-30//SN#107			M-23332/0,3 cc		
	0	2	4	0	2	4	0	2	4
	26.31	26.35	26.34	25.20	25.00	24.90	28.60	28.50	28.30
	26.32	26.35	26.35	25.25	25.05	24.85	28.55	28.50	28.35
	26.31	26.35	26.35	25.15	25.00	24.95	28.75	28.45	28.30
	26.32	26.35	26.36	25.20	25.15	24.95	28.65	28.35	28.30
	26.53	26.35	26.36	25.20	25.10	24.95	28.60	28.50	28.30
Average	<b>26.36</b>	<b>26.35</b>	<b>26.35</b>	<b>25.20</b>	<b>25.06</b>	<b>24.92</b>	<b>28.63</b>	<b>28.46</b>	<b>28.31</b>
Stdev (%)	<b>0.24</b>	<b>0.02</b>	<b>0.75</b>	<b>0.18</b>	<b>0.36</b>	<b>0.11</b>	<b>0.26</b>	<b>0.23</b>	<b>0.08</b>
Repeatability	Good (below 1%)			Good (below 1%)			Good (below 1%)		

**Table 4.** The Output of OB-85 RT: August 7, 2019 at the Gamma Calibration Facility in PTKMR-BATAN

SDD		Without Absorber		
r [cm]	K <sub>a</sub> [μGy/h]	Hp (10) [μSv/h]	H*(10) [μSv/h]	X [mR/h]
50	103672	125444	124408	11820
100	25918	31361	31102	2955
200	6480	7840	7775	739

The output of OB-85 in Table 4 was used for calibration of gamma RMIs (Survey meter and APD). If the survey meter reading unit is μGy/h, use the Air Kerma rate. Survey meter was put at SDD 50, 100 or 200 cm, it depends on the maximum reading of the Survey meter (SM). If the maximum reading was 10,000 μGy/h, the calibration should be carried out at SDD 200 cm. If the unit of SM reading is μSv/h, use the reference reading of the ambient equivalent dose rate, H\*(10) μSv/h. Calibrate the SM at SDD 50, 100 or 200 cm, depending on the maximum reading of the SM. If the maximum reading was 10,000 μSv/h, then the calibration should be carried out at SDD 200 cm.

If the RMIs reading unit is mR/h, use the reference reading of Exposure rate, X. Perform calibration at SDD 50, 100 or 200 cm depending on the maximum RMIs reading. If the maximum reading was 1000 mR/h, then calibration should be carried out at SDD 200 cm.

The uncertainty of RMIs calibration depends on the magnitude of Type A and Type B uncertainties. The Calibration Factor of RMIs =  $\frac{\text{Reference Reading}}{\text{Reading of RMI}}$ . The Reference Reading has uncertainty,  $u_{\text{Ref}}$  and the reading

of RMIs has uncertainty,  $u_{\text{RMI}}$ . So, the combined uncertainty of CF,  $u_c(\text{CF}) = \sqrt{u_{\text{Ref}}^2 + u_{\text{RMI}}^2}$ . And the  $U_{\text{exp}} = k \times u_c$ ,  $k$  = coverage factor.

The combined uncertainty value is useful in knowing the level of success in taking measurements. If the type A uncertainty value is too large there is the possibility of the measurement was wrong or the equipment used does not match the range, if there is such a case then the measurement must be repeated in various ways, for example repeating the measurement several times or replacing experimental devices with tools that have a higher accuracy limit (more accurate).

## 5. Conclusion

To determine the width of the radiation field of the OB-85, stability and repeatability check of the detector should be performed. Determination of the width of the OB-85 was done by three kind of IC. The width of radiation field of the OB-85 was 18 cm for SDD = 50 cm and 36 cm for SDD = 100 cm. The width of the radiation field does not depend on the type of detector used to measure but it depends on the set-up of calibration facility, geometry/shape of source, diameter of collimator, and SDD.

## Acknowledgment

The authors thank to the Head of Radiation Metrology Division and the Head of PTKMR-BATAN for their cooperation in allowing the author and colleagues to do this research.

## References

- [1] Peraturan Kepala Badan Pengawas Tenaga Nuklir Nomor 1 (2006) tentang Laboratorium Dosimetri, Kalibrasi Alat Ukur Radiasi Dan Keluaran Sumber Radiasi Terapi, dan Standardisasi Radionuklida BAPETEN Jakarta.



- [2] Safety Report Series No. 16, (2000), Calibration of Radiation Protection Monitoring Instruments, IAEA, Vienna, Austria.
- [3] IAEA Safety Standards for Protecting People and the Environment, (2011), Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, Interim Edition, A General Safety Requirements Part 3, No. GSR Part 3 (Interim), IAEA, Vienna.
- [4] Joint Committee for Guides Metrology (JCGM 107) – Evaluation of measurement data – Applications of the least-squares method (ISO/IEC Guide 98-5), IAEA, Vienna, Austria.
- [5] Anonymous, "Ionization Chambers". (2017), Health Physics Historical Instrumentation Collection. Oak Ridge Associated Universities. *Retrieved 16 April 2017*.
- [6] Anonymous, Ionization chamber, From Wikipedia, (2019). the last edited on 20 May 2019, at 06:42 (UTC).
- [7] G. RAJAN, J. IZEWSKA, (2000), Radiation Monitoring Instruments, International Atomic Energy Agency, Austria.
- [8] R. Redus, (2018), Fundamentals of Radiation Detection & Measurement, *Retrieved Jan. 2018*.
- [9] V. Lewis, M. J. Woods, Peter Burgess, Stuart Green, John Simpson, Jon Wardle, (2005), Measurement Good Practice Guide No. 49, The Assessment of Uncertainty in Radiological Calibration and Testing, NPL, Teddington, UK.
- [10] JCGM 100: (2008), GUM 1995 with minor corrections Evaluation of measurement data - Guide to the expression of uncertainty in measurement, IAEA, Vienna, Austria.
- [11] ISO 4037-4: (2019), Radiological Protection - X and gamma reference radiation for calibrating dosimeters and dose rate meters and for determining their response as a function of photon energy - Part 4: Calibration of area and personal dosimeters in low energy X reference radiation fields, IAEA, Vienna, Austria.
- [12] IAEA-TECDOC-1585, (2008), Measurement Uncertainty A Practical Guide for Secondary Standards Dosimetry Laboratories, IAEA, Vienna, Austria.