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PROCEEDINGS

2nd International Conference on the Sources, Effects and Risks of Ionizing Radiation (SERIR 2016)

in conjunction with

14th Biennial Conference of the South Pacific Environmental Radioactivity Association (SPERA 2016)

Sanur Paradise Plaza Hotel
Bali, 5-9 September 2016

Organized and hosted by

National Nuclear Energy Agency (BATAN)

in cooperation with

South Pacific Environmental Radioactivity Association

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PREFACE

For the second time the Center for Technology of Radiation Safety and Metrology, National Nuclear Energy Agency of Indonesia (BATAN) was held the 2nd International Conference on the Sources, Effects and Risks of Ionizing Radiation (SERIR2) in Sanur Paradise Plaza Hotel, Sanur, Bali, Indonesia, which was the continued event that already held in last 2013. Similar as previously, Conference dealed with the efforts to enhance data collection and disseminate scientific findings related to the issues of sources, effects and risks of the ionizing radiation, as well as to seek the way of communication among stakeholders (scientific communities, regulatory authorities, and general public) on those issues. This conference was in conjunction with the 14th biennial conference of the South Pacific Environmental Radioactivity Association (SPERA2016) that provides a platform for discussion among scientists on the occurrence, behaviour, impact and measurement of radioactive species present in the environment through natural processes, or resulting from human activities. This international conference also facilitated knowledge sharing on environmental radioactivity and related topics of local and global significance.

In the SERIR2 there were three keynote speakers presented their own expertise : Dr. Stephen Solomon (Principal Scientific Adviser to the CEO, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), Prof. Yoshiyuki Suzuki (Department of Radiation Oncology, Fukushima Medical University), and Dr. Ferhat Aziz (National Nuclear Energy Agency of Indonesia (BATAN)).

In this conference there was a press conference that was attended by local and national journalists. This event was handled by Bureau of Legal, Public Relation and Cooperation (BHHK), BATAN. The speakers were : Dr. Andreas Bollhöfer (President of SPERA), Dr. Justin Lee (Deputy Head of Mission, Department of Foreign Affairs and Trade of Australian Embassy for Indonesia), Dr. Gillian Hirth (ARPANSA), Prof. Dr. Djarot Sulistio Wisnubroto (Chairman of BATAN), and Prof. Dr. Mohammad Nasir (Directorate General of Minister of Research, Technology and Higher Education (Menristekdikti).

In this conference, of 38 papers submitted by authors from three countries (Indonesia, India and Japan), 35 papers were presented as oral and poster presentation. For oral, there were 20 papers presented into two groups of paper (group A, Radiation Exposures and Instrumentation and group B, Occupational Exposures and Health Effects), and for poster there were 15 papers. Totally there were 35 papers that consists of 32 papers from BATAN, one paper from Pachhunga University College-India, one paper from University of Udayana, and one paper from Siloam Hospital.

We would like to thank all those who participated in the conference for the lively discussions as well as the director of the Center for Radiation Safety and Metrology, BATAN upon the opportunity to organize this event as well as the SPERA which was agree to conduct the events in the same venue. In addition, we are also grateful to all the authors for their valuable time and contributions to the conference. Last but not least, the conference would not have been possible without the great help of the staff of the Center and Australian Nuclear Science and Technology Organization (ANSTO), South Pacific Environmental Radioactivity Association (SPERA), Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). We would like to thank all of them for their assistance.

December 2016 SERIR2 Committee

WELCOME ADDRESS BY PRESIDENT OF THE CONFERENCE

His Excellency,
Dr. Muhammad Dimyati, Director General Research and Development, Representing Minister Science, Technology and Higher Education, The Republic of Indonesia;
Prof. Dr. Djarot SulistioWisnubroto, Chairman of National Nuclear Energy Agency (BATAN);
Dr. Andreas Bollhöfer, President of South Pacific Environmental Radioactivity Association (SPERA);
Dr. Justin Lee, Deputy Head of Mission, Department of Foreign Affairs and Trade of Australian Mission for Indonesia; and
Dr. HendigWinarno, Deputy Chairman of BATAN;

Distinguished keynote speakers,
Chairman of the organizing committee,
Participants, Ladies and Gentlemen,

Good Morning and Assalamu-Alaikum Wr.Wb.

On behalf of the National Nuclear Energy Agency (BATAN) of Indonesia, it is my great pleasure to welcome you to the "2nd International Conference on the Sources, Effects and Risks of Ionizing Radiation (SERIR) and 14th Biennial International Conference of SPERA", jointly organized by South Pacific Environmental Radioactivity Association (SPERA) and National Nuclear Energy Agency (BATAN), particularly The Center for Radiation Safety Technology and Metrology. I wish to welcome you to be in a beautiful Bali Island here.

This second International Conference on the SERIR is a continued of the first scientific meeting that had been done here in the same place three years ago. As in the first SERIR, this Conference is held under an urgent need to give contribution to the works of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The 2nd International Conference on the SERIR will be a 1-day conference (5 September). This conference is aimed to disseminate scientific findings related to the issues of sources, effects and risks of ionizing radiation, and to communicate with stakeholders (scientific communities, regulatory authorities and general public).

Ladies and Gentlemen,

Ionizing radiation is generated in a range of medical, commercial and industrial activities. The most familiar and the largest of these sources of exposure is medical X-rays. Natural radiation contributes about 88% of the annual dose to the population, and medical procedures contribute most of the remaining 12%. Natural and artificial radiation are not different in kind of effect. Ionizing radiation has always been present in the environment and in our bodies. However, we can and should minimise unnecessary exposure to significant levels of artificial radiation. Ionizing radiation is also very easily detected. There is a range of simple, sensitive instruments capable of detecting minute amounts of radiation from natural and anthropogenic sources.

The Organizing Committee has invited contributions, academic and practice-based paperson all aspects of the following two topics: Radiation Exposures and Instrumentation; and Occupational Exposures and Health Effects, induced by Medical Radiation uses and Environmental/Natural Radiation. Some of oral and poster presenters will deliver those topics in the afternoon.

This Conference has attracted more than 80 participants from 6 countries. About 39 scientific papers will be presented by their authors orally or as posters. This event will offer you plenty of opportunities for extensive discussions, making of new contacts and strengthening the existing relationships after the oral presentations, during the poster sessions, while visiting the exhibition by SPERA or at the other events.

For the SPERA 2016, the 14th Biennial Conference of the SPERA, to be held 6-9 September, will provides a platform for discussion and debate among scientists on the occurrence, behaviour, impact and measurement of radioactive species present in the environment through natural processes, or resulting from human activities.

The joint conference will include a one-day workshop on Trends in Environmental Sample Preparation on the 6th September, facilitated by The Radiochemistry Division of the Royal Australian Chemical Institute (RACI). The workshop will present an overview of the fundamentals, procedures, and applications of both historical and the most recently developed sample preparation techniques for the extraction, clean up, and concentration of radionuclides from environmental samples

Participants, Ladies and Gentlemen.

In this opportunity, I would like to thank to honorable three invited speakers who have been able to be here, Dr. Stephen Solomon, from Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)-Australia, Prof. Dr. Yoshiyuki Suzuki, MD, from Fukushima University-Japan; and Dr. Ferhat Azis, from BATAN-Indonesia**.** All of them are the prominent scientists in their own field and will providea comprehensive overview of the current status of the global sources, effects and risks of ionizing radiation.

I look very much forward to this Conference and hope there will be warm discussion, because this Conference is open for everybody to give a view, and certainly we will do our best to make sure that the floor is really life. So, please be prepared to give comments and questions for the topics to be delivered by the speakers and presenters.

In this occasion, I would also like to thank the organizer and resource persons who have made this event possible, and who I am sure will be working tirelessly to ensure the success of the conference and workshop over the next few days.

Finally, I wish all of you will enjoy being in Bali, which is one of 16 Most Beautiful Islands in the World. Bali is a feast for the senses. Bali's spirit will wash over you like a warm, tropical wave.

Thank you and Wassalamu-Alaikum WrWb.
President of the Conference
Susetyo Trijoko, M.App.Sc.

OPENING REMARKS
MINISTER OF RESEARCH, TECHNOLOGY AND HIGHER EDUCATION

(Represent by Director General Research and Development)

Honorable;
1. Dr. Andreas Bollhofer (President of SPERA)
2. Deputy Head of Mission, Department of Foreign Affairs and Trade of Australian Embassy for Indonesia
3. Prof. Dr. Djarot Sulistio Wisnubroto, Chairman of Batan
4. All Experts, Participants
5. Distinguish Guest, Ladies and Gentlements

First of all, let us thanks Allah SWT for His blessings; we can be here to attend this International Conference. On behalf of Ministry of Research, Technology and Higher Education, I would like to express my gratitude to all of you, for participating 2th International Conference on the Sources, Effects and Risk of Ionizing Radiation (SERIR) and 14th Biennial International Conference on SPERA in the beautiful island of Indonesia…called BALI.

Delighted Ladies and Gentlemen,

The development of science and technology in the field of health, food, and energy is very progressive. Many researchers doing very sportive competitions to express their knowledge to support the human being. In the other hand, there are many obstacles should be break it out by the researchers to reach the research goals. This forum can be use as an arena to prove that we are capable of doing it. But we need to keep our awareness that whatever the level of research we present now; we should not merely stop at research paper or conceptual design. We must continue and create research outputs that are ready to be commercialized and giving positive impact to the people. Therefore, the benefit of research can be optimized for the good and prosperity of Indonesian people and the world. And with this spirit, the Ministry of Research, Technology and Higher Education support the mutually-benefit linkage between researchers and industries, in order to minimize their mismatch.

To move further, the Ministry of Research, Technology and Higher Education has had and will continue to push and facilitate research outputs that are ready to be used by the people, to be synergized with other research outputs, to give greater benefits and multiplier effects to the community. For example, Indonesian Institute of Science (LIPI) has invented fertilizer that can make paddy stands out of many pests, while Bogor Agricultural Institute has invented new paddy variety that can yield more than 10 ton per hectare. Research and Development of Ministry of Agriculture had invented paddy field management with Jarwo-system that can improve paddy field productivity. Each of the inventions is directly benefiting the user, but synergizing them through government support, will create much greater benefits, and direct impact for the people, mainly local people.

Delighted Ladies and Gentlemen,

Through this conference, hopefully the discussion will lead toward acceleration of people prosperity. We should not put too much effort on just debates that only satisfying researchers themselves. We have to do more than that. Scientific debates outputs that have been perfectly completed can be posted in the international journals, so they could be used to push forward the acceleration of science development in the world.

Once again, I hope that the conference output will provide positive impact through science and technology development, that is benefiting the community.

To all overseas participants, I welcome you in Bali, a beautiful and peaceful island. Enjoy your stay and hope that the serenity of the island inspires you to create changes for a better future.

Finally, by saying BISMILLAH…. I open 2nd International Conference on the Sources, Effects and Risk of Ionizing Radiation (SERIR2) and 14th Biennial International Conference on SPERA2016.

May Allah SWT, the God Almighty give us His Blessing.
Wabilahi Taufiq Walhidayah, Wassalamualaikum Wr. Wb.

Bali, 5 September 2016
Minister of Research, Technology and Higher Education
Mohamad Nasir

Press Conference (organized by BHHK)

	**Dr. Andreas Bollhöfer** (President of SPERA)
	**Dr. Justin Lee** (Deputy Head of Mission, Department of Foreign Affairs and Trade of Australian Mission for Indonesia)
	**Dr. Gillian Hirts (ARPANSA)**
	**Prof. Dr. Djarot Sulistio Wisnubroto (Chairman of BATAN)**
	**Dr. Muhammad Dimyati** (Director General Research and Development, Ministry of Research, Technology and Higher Education, Kemenristekdikti)

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"Cutting Edge Radiotherapy" Including Combination Therapy with Immunotherapy)

Keynote Speaker III

Dr. Ferhat Aziz (*National Nuclear Energy Agency of Indonesia*)
"Environment Radioactivity Monitoring Activities in Indonesia and Its Public Concerning"

Radioactivity Concentrations in Soil Surrounding Experimental Power Reactor Development Plan in Serpong of Indonesia

Makhsun, Dadong Iskandar and Wahyudi

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Abstract. *The evaluation of environmental radioactivities measurements data surrounding RDE (Reaktor Daya Eksperimental/Experimental Power Reactor) development plan in Serpong Nuclear Area (KNS) along year 2015 is presented. Measurements of environmental radioactivities were carried out from radius 0 km to 50 km. The environmental radioactivities of ^{226}Ra, ^{232}Th, ^{228}Th, ^{40}K and ^{137}Cs were measured from the samples of soils with the deepness of 0-5 cm and 5-20 cm. The sampling strategy is done by dividing the area into seven circular zones over 16 angular sectors with the purpose of knowing the distribution of radioactivities in the environmental surrounding KNS, particularly ^{137}Cs, in conducted to the investigation of the releasing radioactivities from GAS reactor stack. The results show that the average concentration of natural radioactivities of ^{226}Ra, ^{232}Th, ^{228}Th and ^{40}K in the soil with the deepness of 0–5 cm is 21.27±2.39, 32.22±3.46, 30.59±3.15 and 172.89±17.38Bqkg^{-1}, respectively as well as the deepness of 5–20 cm is 22.88± 2.61, 33.64± 3.71, 30.59±3.10 and 68.32 ±7.35 Bqkg^{-1}, respectively. In comparing to other investigations in different locations in the world, it was found that the concentrations of natural radioactivity were lower than those of world average values except the ^{232}Th.The average concentration of ^{137}Cs in soil with the deepness 0–5 and 5–20 cm viewed over the angular sector is in range of <MDC –1.43±0.21 and <MDC –0.42±0.08 Bqkg^{-1}, respectively while viewed over radius from KNS is in range of 0.15±0.05–0.86±0.21 and <MDC –0.25±0.18 Bqkg^{-1}, respectively. The concentrations of ^{137}Cs in soils, either in the deepness of 0–5 or 5–20 cm, are independent to the radius from KNS indicating that the distributed ^{137}Cs in soil is not from KNS. In other side, the highest average concentration of ^{137}Cs is to the south east direction from KNS while the dominant wind direction in that area was to the west. It confirms that the distributions of ^{137}Cs in the soil are not from KNS.*

Keywords: RDE, Serpong Nuclear Area, environmental radioactivities in soil, ^{137}Cs.

Introduction

Serpong Nuclear Area (KNS)

Serpong Nuclear Area (KNS) is located in Research Center of Science and Technology of Indonesia (Puspiptek) area. It is a multi facility research institutes including a research nuclear reactor belonging to BATAN which started operation in August 1987. In addition to research reactor nuclear, there are fuel fabrication facility, radio isotope industry, waste management facility and radioactive waste storage facility. In order to develop KNS, the RDE (*Reaktor Daya Eksperimental*/Experimental Power Reactor) is being planned to be built in this area. Geographically, the position of RDE is in the coordinate of S6.35757 E106.66087 about 27 km south west of Jakarta, 36 km north of Bogor and 22 km south of Tangerang.

According to Article III.A.6 IAEA Statute, the safety standards establish safety standards for the protection of health and minimization of danger to life and property. Safety standards include Safety Fundamentals, Safety Requirements and Safety. These standards are written mainly in the style of regulation, and binding IAEA for its own program. The primary users are the regulatory bodies in the Member States and other national authorities. Referring to the act No. 32 year 2009 article 22 paragraph (1) on the protection and management of the environment, it states that any business and/or activities which have an important impact on the environment must have the environmental impacts analysis (EIA). Government regulation No. 27 year 2012 article 2 paragraph (1) on the environmental permit states any business and/or activities which mandatory have environmental impacts analysis must have environmental permit and article 3 paragraph (1) describes every business and/or activities which have an important impact on the environment must have the EIA. Minister of environment regulation No. 05 year 2012 on types of business plan and/or activities which mandatory have EIA annex I point M in field of nuclear states the construction and operation of nuclear reactors must have documents of EIA. As the initiator of the KNS development, BATAN requires to prepare the environmental impact studies.

Division of Radioecology included in the Center for Technology of Radiation Safety and Metrology (PTKMR)-National Nuclear Energy Agency of Indonesia (BATAN) is tasked to prepare the environmental radioactivity footprint studies. This task includes the measurements of the environmenttal radioactivities surrounding KNS in radius 0 to 50 km. The objectives of these measurements are:

(a) To measure the environmental radioactivity in samples of soil, water, airborne particulates and biota.
(b) To detect the radioactivity releases from the reactor, if any.
(c) To measure the environmental radioactivity exposure.

(d) To monitor the environmental radioactivity during the KNS development.

The operational of the environmental radio-activities footprint study has been started from early 2015. This studyis focused on the assessment of the environmental radioactivities and environmental gamma exposures level surrounding KNSin radius 0 to 50 km.

Background of The RDE Project

One of the featured programs in BATAN strategic plan year 2015-2019 is the construction of the Experimental Power Reactor (RDE). RDE is a nuclear power plant which is added with research facilities. The operation of RDE andother nuclear facilities are expected to provide a tremendous positive impact. The existence of RDE can accelerate the development of nuclear technology in Indonesia therefore Indonesia will excel in Southeast Asia region. The RDE applications will increase the value-added of local natural resources products. It may be used as a model to meet the industry's need of raw materials which has been dependent on imports. The success of Indonesian people in the construction, operation, maintenance and utilization of the RDE will increase the public acceptance on nuclear technology in order to fulfill the obligation of the state in social welfare. Preserve the environment and rising standards of living as well as foreign exchange from local mineral resource processing sector are the impact of the demands of the application of the safe nuclear technology. It will increase the international confidence to the national ability in the mastery of high technology.

Nuclear power plants produce electrics in the same manner as the usual power plants that use oil and coal fuels. In those electric power plants, electricity is obtained by heating the water into steam and letting the steam flows rotatea turbine. The main difference of the nuclear power plants and fossil fuels power plants is the method of the heat production. Thermal energy in the nuclear power plants is generated by splitting atom nuclei while in the fossil fuels power plant, the thermal energy is derived from fuel combustion processes. Nuclear power plants have many advantages than conven-tional power plants. They do not produce smoke and dust pollutants as the combustion result therefore it is known as clean power plants. They produce electrics in relative low price and more efficient compare to the other. More than one third of thermal energy generated in the reactor can be converted into electric energy. However the utilization of nuclear energy must pay attention the safety and environ-mental aspects. Particularly, in Indonesia the political aspect should be more considered.

RDE or experimental power reactor is a nuclear reactor that can be used for power and heat generation as well as to produce hydrogen. Due to its characteristic as the experimental, the operation of this nuclear reactor is more for experimental purposes in increasing mastery of technology. Mastery on reactor technology of these three things is very important in view of the Indonesian people still lack electricity. Hydrogen production from RDE can be used as raw material for plant fertilizer production where it is needed in increasing agricul-tural productivity. The residual heat energy from electricity generation can also be used for the needs of the industry processing.

Environmental Radioactivity

Environmental contains radioactivities since the universe was created. There are two types of radioactivity contained in environment: natural radioactivity and artificial radioactivity. Natural radioactivity is an incident of atomic decays that occurs spontaneously without stimulations from outside. It consists of primordial and terrestrial radioactivity. The contributor to primordial natural radioactivity is from three entirely separates radionuclide series. The first series is known as naturally ^{238}U series. It is the predominant contri-butor and longest series of primordial radionuclide in the earth. The average content of ^{238}U in the Earth's crust has been estimated to be 2.7 mg/kg and its concentrations enhance to be 120 mg/kg in phosphate rocks (Padam et al., 1996). The second series originated with the second most commonly occurring isotope is called as ^{235}U series.The third series is known as ^{232}Th. The average content of ^{232}Th in the Earth's crust is about 9.6 mg/kg (Firestone et al., 1996). Enhanced levels of ^{238}U, ^{235}U and ^{232}Th might be present in areas that have rich in natural radioactivity. These series arise because of the nature changing of daughter from its parent due to loss of either a beta particle or an alpha particle from an atom. When an atom decays with loss a beta particle, the charge on the nucleus is increased by one therefore the atomic number of the atom increases by one. When an alpha particle is emitted in decay process, the atomic number of the atom is reduced by two and its atomic weight by four.

Not all radionuclide occur as spontaneous nuclear reactions. The radioactivity also occurs when stable isotopes bombarded with neutrons, it may change to be radioactivity. This method of inducing a nuclear reaction is termed as artificial radioactivity. This radioactivity which has not spontaneous atomic decay could now be observed. The artificial radioactivities contained in environ-mental usually are from nuclear power plants, nuclear experiment, radioactive therapies in hospitals and utilization of radioactivity in industries. One of the artificial radioactivities produced from nuclear power plants and nuclear experiments is ^{137}Cs. Now, ^{137}Cs was distributed globally into the environment as a consequence of nuclear weapon tests and some nuclear accidents, most notably the Chernobyl and Fukushima Daichi disasters. Measurement of ^{137}Cs in environmental samples as the monitoring of the releasing artificial radioactivities into environment has been reported by researchers (R. Blagoeva et al. 1994, C, Gil-Garcia at al. 2007, M.H. Lee et al. 1996).

Methodology

Sampling Strategies

The geographical area of the environmental radioactivity measurements surrounding KNS is shown in fig. 1. The area is divided into seven circular zones over 16 angular sectors. The seven zones are named as: zone-1 (radius: 0-1 km), zone-2 (radius: 1-3 km), zone-3 (radius: 3-5 km), zone-4 (radius: 5-10 km), zone-5 (radius: 10-20 km), zone-6 (radius: 20-35 km) and zone-7 (radius: 35-50 km). The angular sectors which have angular degree 22.5^{o} are named as: A, B, C, D…. etc. However, the sampling is carried out only in land therefore, totally, there are 109 monitoring location starting from grid-1A to grid-7P except the gridsof A7, B7 and P7. In each grid, it was measured the gamma exposure rate and collected the environmental radioactivity samples of soil, sediment, water, biota and air. About 2 kg of each sample of soil and sediment were collected. The soil was collected in the deepness of 0-5 cm and 5-20 cm. Water (surface water and/or groundwater) was collected in volume of 20 liters. Biota of grass species were collected about 1 kg wet. The sampling of airborne radioactivity used a Whatman glass microfiber filters that was installed in the high volume air sampler (HVAS) model HV-1000F produced by SIBATA. The sampling was conducted for 24 hours in the flow rate of 1000 litter per minute. The number and type of samples that had been measured for environmental radioactivity during year 2015 were given in Table 1. However, this paper only takes part in the analysis of natural radioactivity concentrations in soil.

Preparations and Measurements

Keselamatan Lingkungan laboratory is the only nationally recognized laboratory in Indonesia for the study of radioactivity contained in environmental samples. The laboratory is under the structure of environmental safety sub-division that included in the radioecology division. It consists of radiochemistry and radioactivities measurement laboratories. The laboratory is completed with state of the art equipments in line with the developments of radioactivity analysis and measurement method. The preparations and measurements of collected samples in case of KNS environmental radioactivity footprint studies are carried out in this laboratory. The soil samples are prepared by means of dried and crushed. The powders are then inserted to the marinelli, sealed and weighed. All of the prepared samples are measured using a gamma spectrometer after setting for three weeks until the radioactivity equilibrium.

Table 1. Number and type of samples measured for environmental radioactivity during year 2015.

Sample matrix	Species	No. of samples
Solid	Soil in deepness of 0-5 cm	70
	Soil in deepness of 5-20 cm	29
	Sediment	15
	Grasses	52
Liquid	Surface water	3
	Groundwater	35
Airborne	Air filter	18
Exposure	Gamma exposure	68

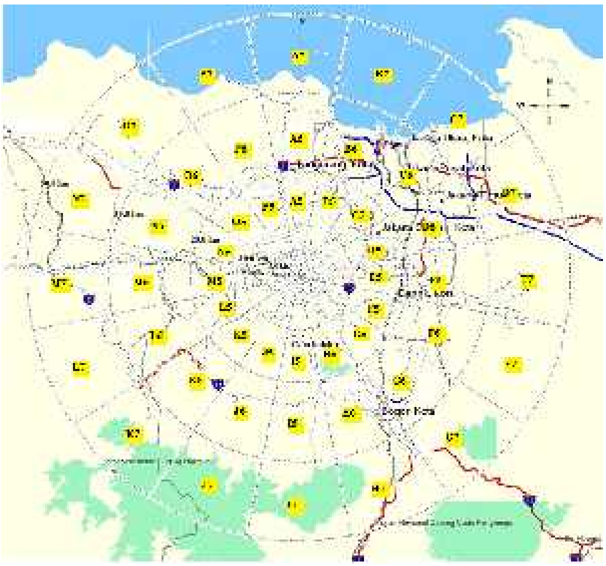

Figure 1. Geographical area of the environmental radioactivity measurements surrounding KNS

Before doing any measurement, the counting system is necessary to be calibrated with a standard source in the same geometry as those of the samples. To prepare such a standard, a known quantity of standard reference material (SRM) was filled in a marinelli identical to the sample marinelli.A detector HPGe Type GEM 60-5 with relative efficiency of 35% and resolution of 1.81 keV at 1.33 MeV was used for measurement of ^{226}Ra, ^{232}Th,^{228}Th,^{40}K and ^{137}Cs concentration. The detector was enclosed in a 10 cm thick compact lead shield. The counting of the samples was obtained by analyzing the spectra acquired from MCA (Multi Chanel Analyzer) by employing a PC with associated software. After adjustment of necessary parameters, the samples were put on the detector and counted for 17 hours. The energy peaks of 295.21, 351.93, 609.32, 1120.29 and 1764.52 keV were consider for calculation of ^{226}Ra, 338.42, 911.16 and 968.97 keV for ^{232}Th, 238.63, 583.19 and 2614.53 for ^{228}Th, 1460.80 keV for ^{40}K and 661.66 keV for ^{137}Cs activities. The minimum detection concentrations (MDC) of ^{226}Ra, ^{232}Th,^{228}Th, ^{40}K and ^{137}Cs for this measurement are 0.00524, 0.00515, 0.00339, 0.01456 and 0.00099 Bq/kg, respecttively. To calculate radioactivity concentration, equation 1 is used in these measurements.

$$A = \frac{CPS}{E\,Y\,W\,f_c} \qquad (1)$$

Where

CPS = net count per second
E = counting efficiency
Y = energy yield
W = sample weight (kg)
F_c = correction factor (include: summing in, summing out, decay factor, recovery factor, attenuation factor and growth factor)

Result and Discussion

Natural Radioactivity Concentration

The measurement results of environmental radioactivities concentrations in soil samples surrounding KNS are shown in Table 2 to Table 5. The data are grouped base to the radius from the center of KNS and angular sector over the deepness of the soil sample (0-5 cm and 5-20 cm). Radiuses indicate the circular areas which have a certain range from the center of KNS. Angular sectors indicate the segment areas in circle arc in a certain direction. The purpose of the grouping data into angular sector and radius is also to investigate the dispersion of the releasing radioactivity from GAS reactor stack, especially ^{137}Cs. Table 2 and 3 shows the average concentration of environmental radioactivity in soil with deepness 0-5 cm viewed over the angular sector and radius from KNS respectively. The average concentrations of ^{226}Ra, ^{232}Th,^{228}Th and ^{40}K in view of angular sector are in ranges of 12.66±1.57 to 29.82±3.21, 21.63±2.45 to 43.79±4.56, 22.58 ±2.70 to 41.75±4.18 and 28.54±3.89 to 993.45 ±95.89 Bq kg^{-1}, respectively. Except ^{40}K, the highest values of those are in angular sector O (at 22.6 degree anti clockwise direction from KNS). The highest average value of ^{40}K is in angular sector I (in the south direction from KNS).

The average natural radioactivity concentrations of ^{226}Ra, ^{232}Th, ^{228}Th and ^{40}K viewed over radius from the center of KNS are in ranges of 17.86±2.40 to 22.70±2.57, 28.38±3.19 to 34.08± 3.54, 26.38±2.79 to 33.56±3.54 and 58.20±6.65 to 634.85±61.47 Bqkg^{-1}, respectively. Excluding ^{226}Ra which has the highest average value in radius 20-30 km, the highest average values of those are in radius 35-50 km. The most dominant contribution of ^{226}Ra,

^{232}Th and ^{228}Th comes from grid O7 ie 47.81±4.82, 73.55±7.28 and 68.93± 6.68 Bqkg^{-1}, respectively. This grid includes in region Ciherang, Carenang-Serang while the most dominant contribution of ^{40}K is from grid I7 (4714.86±452.24 Bqkg^{-1}) which includes in region Cipayung, Megamendung-Bogor.

If the calculation includes the entire measured samples without looking at the grouping of angular sector and radius from KNS but the deepness of 0-5 cm, the average concen-tration of ^{226}Ra, ^{232}Th, ^{228}Th and ^{40}K surrounding KNS is 21.27±2.39, 32.22±3.46, 30.59±3.15 and 172.89±17.38Bqkg^{-1}, respectively. In comparing to other investigations in different locations in the world as shown in Table 6, it was found that the concentrations of natural radioactivity were lower than those of world average values except the ^{232}Th. The value of ^{232}Th was almost matching to that of world average. It was also observed that the values were within the range of other country/zone values except ^{226}Ra and ^{232}Th. The value of ^{226}Ra was lower than that of the Savar (Bangladesh) while ^{232}Th was higher. However, the data of other countries and world averages are the concentration of natural radioactivities in soils without looking at the deepness.

Table 4 and 5 show the average concentrations of ^{226}Ra, ^{232}Th, ^{228}Th,^{40}K and ^{137}Cs in soil with deep-ness 5-20 cm viewed over the angular sector and radius from KNS respectively. The concentrations of natural radioactivities of ^{226}Ra, ^{232}Th, ^{228}Th and ^{40}K viewed over angular sector are in ranges of 14.62± 1.69 to 52.16±7.91, 27.26± 2.91to 84.74± 12.17, 23.05±2.45 to 39.62±3.91 and 14.11±3.06 to 200.67 ±19.61 Bqkg^{-1}, respectively. The highest value of ^{226}Ra and ^{232}Th is in angular sector L, ^{228}Th in angular sector O and ^{40}K in angular sector N. Those angular sectors are in the western part of KNS. In case viewed over radius from KNS, the concen-trations of ^{226}Ra, ^{232}Th, ^{228}Th and ^{40}K are in ranges of 14.85-26.62, 28.25-36.33, 25.65-35.71 and 29.21-166.42 Bqkg^{-1}, respectively. The highest value of ^{226}Ra and ^{232}Th is in radius 3-5 km, ^{228}Th in radius 10-20 km and ^{40}K in radius 20-35. However, an angular sector (J) and a radius (35-50 km) have not been measured. If they are viewed over the entirety data, the most dominant contribution of ^{226}Ra and ^{232}Th is from grid L3 (in Rumpin), ^{228}Th from grid O1 (in Puspiptek) and ^{40}K from grid H3 (in Gunung Sindur). The values of those are 52.16±7.91, 84.74± 12.17, 59.53±5.76 and 273.22±26.50 for ^{226}Ra, ^{232}Th, ^{228}Th and ^{40}K, respectively. In calculation of entire measured samples, it was found that the average concentrations of ^{226}Ra, ^{232}Th, ^{228}Th and ^{40}K surrounding KNS are 22.88±2.61, 33.64±3.71, 30.59 ±3.10 and 68.32±7.35 Bqkg^{-1}, respectively. Except ^{40}K, the values are almost matching to those of the deepness 0-5 cm.

Table 2. Average concentration of environmental radioactivity in soil with the deepness of 0-5 cm surrounding KNS viewed over the angular sector.

Angular Sector	^{226}Ra (Bqkg^{-1})	^{232}Th (Bqkg^{-1})	^{228}Th (Bqkg^{-1})	^{40}K (Bqkg^{-1})	^{137}Cs (Bqkg^{-1})
A	18.98±2.08	28.74±3.04	28.42±2.84	76.09±7.90	0.28±0.06
B	18.41±2.06	27.18±2.92	25.75±2.62	78.51±8.10	0.05±0.02
C	19.82±2.38	29.60±3.33	29.10±3.04	91.49±10.03	0.18±0.22
D	21.34±2.42	35.56±3.79	31.04±3.18	81.99±8.71	0.13±0.04
E	19.66±2.41	32.01±3.61	31.14±3.30	28.54±3.89	0.21±0.05
F	21.36±2.35	33.64±3.53	31.83±3.20	57.50±6.22	0.25±0.05
G	22.20±2.64	33.45±3.82	29.95±3.19	437.46±43.00	1.43±0.21
H	23.19±2.53	33.19±3.49	32.15±3.23	129.61±13.09	0.36±0.06
I	12.66±1.57	21.63±2.45	22.58±2.70	993.45±95.89	0.10±0.21
J	19.94±2.28	28.39±3.10	27.30±2.82	163.06±16.48	0.20±0.03
K	21.76±2.35	36.05±3.74	35.60±3.54	95.49±9.75	0.43±0.08
L	27.53±2.98	35.80±3.78	33.33±3.38	98.22±10.25	0.28±0.06
M	20.87±2.24	30.65±3.19	28.65±2.87	122.05±12.18	0.22±0.05
N	22.52±2.42	35.16±3.65	32.67±3.26	89.99±9.21	<MDC
O	29.82±3.21	43.79±4.56	41.75±4.18	83.84±8.90	0.23±0.05
P	16.34±1.93	26.60±2.93	25.00±2.61	45.50±5.32	0.12±0.03
Range	12.66 – 29.82	21.68 – 43.79	22.58-41.74	28.54 – 993.45	<MDC -1.43
Entirety	21.27± 2.39	32.22± 3.46	30.59± 3.15	172.89± 17.38	0.31± 0.08

Table 3. Average concentration of environmental radioactivity in soil with the deepness of 0-5 cm surrounding KNS viewed over the radius from central KNS.

Radius (km)	^{226}Ra ($Bqkg^{-1}$)	^{232}Th ($Bqkg^{-1}$)	^{228}Th ($Bqkg^{-1}$)	^{40}K ($Bqkg^{-1}$)	^{137}Cs ($Bqkg^{-1}$)
0-1	21.31±2.36	33.36±3.53	32.15±3.24	80.49±8.47	0.24±0.05
1-3	17.86±2.40	28.38±3.19	26.38±2.79	58.20±6.65	0.15±0.05
3-5	22.61±2.47	33.12±3.48	31.70±3.19	64.38±6.79	0.30±0.11
5-10	20.78±2.36	32.90±3.53	31.01±3.18	133.03±13.60	0.20±0.04
10-20	21.32±2.43	32.19±3.50	30.07±3.11	68.83±7.62	0.21±0.05
20-35	22.70±2.57	31.30±3.45	29.12±3.03	303.03±29.75	0.86±0.21
35-50	22.30±2.41	34.08±3.54	33.56±3.54	634.85±61.47	0.19±0.04
Range	17.86–22.70	28.38–34.08	26.38–33.56	58.20–634.85	0.15–0.86
Entirety	21.27± 2.39	32.22± 3.46	30.59± 3.15	172.89± 17.38	0.31± 0.08

Table 4. Average concentration of environmental radioactivity in soil with the deepness of 5-20 cm surrounding KNS viewed over the angular sector.

Angular Sector	^{226}Ra ($Bqkg^{-1}$)	^{232}Th ($Bqkg^{-1}$)	^{228}Th ($Bqkg^{-1}$)	^{40}K ($Bqkg^{-1}$)	^{137}Cs ($Bqkg^{-1}$)
A	14.62 ± 1.69	28.21±2.97	25.08±2.55	39.52±4.52	0.05±0.02
B	17.69 ± 2.00	27.58±2.96	27.33±2.79	48.51±5.39	0.16±0.03
C	17.80 ± 2.03	27.26±2.91	24.17±2.49	64.82±7.02	0.11±0.04
D	18.41 ± 2.14	34.86±3.79	34.62±3.51	30.78±3.89	0.17±0.37
E	16.24 ± 2.09	28.77±3.44	30.99±3.25	14.11±3.06	<MDC
F	26.41 ± 2.84	32.12±3.43	32.92±3.32	132.18±13.32	<MDC
G	36.93 ± 3.85	31.99±3.36	29.09±2.95	30.03±3.69	0.40±0.58
H	27.21 ± 2.88	32.81±3.46	31.92±3.20	140.77±13.96	0.06±0.03
I	19.28 ± 2.17	31.04±3.28	24.94±2.52	149.53±14.82	0.35±0.07
J	Not Measured	Not Measured	Not Measured	Not Measured	Not Measured
K	21.89 ± 2.40	35.13±3.64	32.99±3.31	77.32±8.14	0.42±0.08
L	52.16 ± 7.91	84.74±12.17	32.52±3.25	21.60±2.78	0.32±0.07
M	21.76 ± 2.34	31.89±3.28	28.88±2.89	74.48±7.76	0.41±0.08
N	27.33 ± 2.86	37.93±3.90	34.80±3.45	200.67±19.61	<MDC
O	28.00 ± 2.97	39.46±4.09	39.62±3.91	86.40±8.97	0.02±0.01
P	16.05 ± 1.94	24.94±2.82	23.05±2.45	60.28±6.87	<MDC
Range	14.62 – 52.16	27.26 – 84.74	23.05 – 39.62	14.11 – 200.67	<MDC – 0.42
Entirety	22.88 ± 2.61	33.64 ± 3.71	30.59 ± 3.10	68.32 ± 7.35	0.15 ± 0.11

Table 5. Average concentration of environmental radioactivity in soil with the deepness of 5-20 cm surrounding KNS viewed over the radius from central KNS.

Radius (km)	^{226}Ra ($Bqkg^{-1}$)	^{232}Th ($Bqkg^{-1}$)	^{228}Th ($Bqkg^{-1}$)	^{40}K ($Bqkg^{-1}$)	^{137}Cs ($Bqkg^{-1}$)
0-1	24.43±2.65	34.85±3.64	32.40±3.25	74.79±8.02	0.25±0.18
1-3	14.85±2.60	28.25±3.11	27.90±2.88	29.21±3.80	0.19±0.05
3-5	26.62±3.27	36.33±4.39	28.04±2.86	73.55±7.81	0.21±0.04
5-10	15.74±1.92	28.62±3.24	25.65±2.71	67.38±7.44	<MDC
10-20	23.58±2.55	34.86±3.65	35.71±3.57	36.10±4.19	0.02±0.26
20-35	24.55±2.61	35.03±3.66	33.86±3.38	166.42±16.46	<MDC
35-50	Not Measured	Not Measured	Not Measured	Not Measured	Not Measured
Range	14.85– 26.62	28.25 – 36.33	25.65 – 35.71	29.21 – 166.42	<MDC – 0.25
Entirety	22.88 ± 2.61	33.64 ± 3.71	30.59 ± 3.10	68.32 ± 7.35	0.15 ± 0.11

Concentration of ^{137}Cs

The average concentrations of ^{137}Cs in soil surrounding KNS viewed over the angular sector with the deepness 0-5 and 5-20 cm as shown in Table 2 and 4 are in range of <MDC – 1.43±0.21 and <MDC – 0.42± 0.08 Bqkg^{-1}, respectively. The most dominant contribution of those with the deepness 0-5 cm is from grid G6 which located in Sukaraja-Bogor. On the other hand the most dominant contribution of ^{137}Cs in soil with the deepness 5-20 cm is from grid K1 which located in Puspiptek area. In case grid G6, the concentration of ^{137}Cs is 7.68±1.08 Bqkg^{-1}while K1 is 0.71±0.12 Bqkg^{-1}. If the concentration of ^{137}Cs in soil surrounding KNS viewed over the radius from KNS with the deepness 0-5 and 5-20 cm as shown in Table 3 and 5, the values are in range of 0.15±0.05 – 0.86±0.21 and <MDC – 0.25±0.18 Bqkg^{-1}, respectively. Those tables also show the concentrations of ^{137}Cs in soils independently to the radius from KNS. It indicates that the distributions of ^{137}Cs in the soils are not from KNS. In other side, the highest average concentration of ^{137}Cs as shown in Table 2 was in angular sector G (south east direction from KNS) while the dominant wind direction in that area was to the west (BMG, 2007). It confirms that the distributions of ^{137}Cs are not from KNS. It can be concluded that the concentrations of ^{137}Cs in soils surrounding KNS are terrestrial fallout.

Looking to the entire data, it was found that some areas havequite high ^{137}Cs concentration. In the course of these measurements of the soil with the deepness of 0-5 cm, four locations have ^{137}Cs concentration higher than 1 Bqkg^{-1}. Those locations are in grid F4 (1.04±0.15 Bqkg^{-1}), L4 (1.12±0.20 Bqkg^{-1}), G6 (7.68± 1.08 Bqkg^{-1}) and H7 (1.09±0.16 Bqkg^{-1}) which locate in Bojongsari-Depok, Rumpin-Bogor, Sukaraja-Bogor and Ciawi-Bogor, respectively. The concentration accumulation of ^{137}Cs in soils which is deposited by terrestrial fallout is affected by the meteorological factors and soil mineral contents on those related areas (P.N. Chiang et al, 2010; U Bartl et al, 1991). Elements components of soil, especially organically bound Al and Fe oxides greatly influence sorption for Cs. The high contents of Al_p and Fe_p in the soil could absorb Cs^+ ion on the surface by ion exchange and form complexes resulting in maximum sorption of ^{137}Cs. In case of those areas which have high ^{137}Cs concentration, investigation of elements content in those related soils necessary to be carried out.

Conclusion

The construction plan of the Experimental Power Reactor (RDE) in case the development of KNS obliges to do the measurements of environmental radioactivities in soils surrounding that area. The measurements of environmental radioactivities include ^{226}Ra, ^{232}Th, ^{228}Th,^{40}K and ^{137}Cs. The measurements method used in this study either to get the baseline environmental radioactivities data also to evaluate the releasing of radioactivity, especially ^{137}Cs, from GAS reactor stack. The results show that the average concentrations of ^{226}Ra and^{40}K were lower than those of world average values while the ^{232}Th almost match. In comparing to the measurements of several other country/zone, it was observed that the concentrations of ^{226}Ra, ^{232}Th and^{40}K were within the range except ^{226}Ra and ^{232}Th which were outside of the Savar (Bangladesh) range. The concentration of ^{137}Cs in soil with the deepness 0-5 cm in the area of Bojongsari-Depok, Rumpin-Bogor, Sukaraja-Bogor and Ciawi-Bogor was detected more than 1 Bqkg^{-1}.

Table 6. Concentration of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs in soil from some different part of the world compare to present study

Country/Zone	^{226}Ra (Bqkg^{-1})	^{232}Th (Bqkg^{-1})	^{40}K (Bqkg^{-1})	^{137}Cs (Bqkg^{-1})	Reference
Savar, Bangladesh	32–49	19–29	129–527	2–3	Mollah A.S et al, 1994
Bulgaria	12 – 210	7 – 160	40 – 800	287.9 – 827.1*	UNSCEAR, 2000; *Mollah A.S et al, 1994
China	2–440	1–360	9–1800	0.3-12.9*	UNSCEAR, 2000; *Ye Zao et al, 2012
Cairo, Egypt	5.3-66.8	5-37.3	41.5–418	0-35.7	Nada A. et al, 2009
Greece	1–240	1–190	12–1570	1.8-11.1*	UNSCEAR, 2000; *Papaefthymiou H. et al, 2007
India	7–81	14–160	38–760	≤1-2.88*	UNSCEAR, 2000; *Kannan V. et al, 2002
Jordan	16.3-57.3	7.6-16.2	121.8-244.8	1.9-5.3	Karakelle B. et al, 2002
Malaysia	49–86	63–110	170–430	0.05-2.11*	UNSCEAR, 1998; *Zaini H. et al, 2012
Spain	6–250	2–210	25–1650	10–60*	UNSCEAR, 2000; *Gomez E. et al, 1997
Taiwan	44.7-10.6	12.2-44.2	195.3–640	0-12.1	Tsai T.L. et al, 2008
Louisiana, USA	34–95	4–130	43–719	5–58	Delaune R.D. et al, 1986
Present Study	21.27	32.22	172.89	0.31	Depness (0 – 5 cm)
	22.88	33.64	68.32	0.15	Depness (5 – 20 cm)
World average	35	30	400		UNSCEAR, 2000

However, the high concentration of ^{137}Cs in those areas is not from GAS reactor which located in KNS but the terrestrial fallout. High concentration of ^{137}Cs in soils which is deposited by terrestrial fallout is affected by the meteorological factors and soil mineral contents. We suspect those areas have high content of Al and Fe in the soil. The high contents of Al_p and Fe_p could result the maximum sorption of ^{137}Cs.

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Discussions

Q : Prof. H. Heijnis

How did you take different grain size and organic matter content of soil into consideration ?

A : Makhsum

In our research this is not determined yet.