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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

SERIR2

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
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Dr. Ferhat Aziz *(National Nuclear Energy Agency of Indonesia)*
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Cytogenetic Evaluation in Peripheral Blood Lymphocytes of Individuals living in high natural background radiation of Botteng Village, Mamuju

Siti Nurhayati, Sofiati Purnami and Mukh Syaifudin

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Abstract. *Mamuju area in Indonesia recorded has a higher average dose rate compared to other regions and considered as a high natural background radiation area. Inhabitants of Botteng village in Mamuju received radiation exposure higher than other areas in Indonesia. Studies on the cytogenetics status of populations in Botteng are important to know the information about effects of chronic low dose exposures. Aim of this study was to evaluate the cytogenetics status in peripheral blood lymphocytes of Botteng inhabitants using chromosomal aberrations and micronucleus assays. Seventy healthy adult subjects from Botteng and eighteen healthy adult subjects from normal background radiation area were included in this study. Cytogenetic evaluation was conduct using chromosomal aberrations and micronucleus assays. Results showed that there was no statistically different of unstable chromosomal aberrations and micronucleus number in Mamuju and control samples. It was also seen in this study that there was a tendency that MN numbers increase with age in Mamuju and control samples. The mean MN numbers per BNC cells also was higher in females compared to males in all groups. Overall, in can be concluded that chronic low radiation dose exposure in Botteng village has no effect on unstable chromosomal aberrations and MN numbers among Botteng village inhabitants. It is possible that the level of radiation exposure was not adequate to induce significant chromo-somal aberrations in Botteng village inhabitants or the repair process of the DNA damage in individuals from Botteng village was very efficient.*

Keywords: Cytogenetic, Chromosome, Mamuju, Micronucleus, Natural Radiation.

Introduction

There is no area in the world that has no natural radioactivity, because radionuclides can be found naturally in environment. Radionuclides in environment can be classified into three categories which were primordial that formed before the earth creation, cosmogenic as a consequence of cosmic ray interactions, and human produced (Gahrouei et al. 2013). Natural radiation exposure is considered as the major sources of human exposure to ionizing radiation. People living in high natural background radiation areas (HBRA) like Ramsar in Iran and Kerala in India received radiation exposure higher than the worldwide average background dose for a human being (Mortazavi & Mozdarani 2012). Botteng village inhabitants in Mamuju, West Sulawesi Provence also received radiation exposure higher than other areas in Indonesia. This because Botteng village in Mamuju area has been reported for the high radiation dose rate due to the Naturally Occurring Radioactive Material (NORM). Several areas in Mamuju have a radiation dose rate more than 5 mSv y^{-1} (Syaeful et al. 2014). An annual effective dose (H_E) in Botteng village, Mamuju was reach 6,15 ± 0,81 mSv y^{-1} (Alatas et al. 2012). Sohrabi (2013) has classified the HBRA into four categories, which were low (H_E = 5 mSv y^{-1}, medium (H_E = 5-10 mSv y^{-1}), high (H_E = 20-50 mSv y^{-1}) and very high (H_E > 50 mSv y^{-1}). The classification is based on the dose limits of the ICRP and the 2.4 mSv y^{-1} global mean dose value reported by UNSCEAR.

A cytogenetic investigation in peripheral blood lymphocytes of thirty samples from Botteng already conducted by Alatas et al. (2012). They found that there was insignificant difference of stable and unstable chromosome aberrations frequency in Botteng inhabitants compared to those live in normal natural radiation area (NBRA). Aim of this study was to re-evaluated the cytogenetic status in peripheral lymphocytes of Botteng inhabitants using a higher sample size compared to Alatas et al. (2012) study. Cytogenetic evaluation was conduct using classical cytogenetic techniques that studied chromosomes directly by observation and by counting the aberrations in metaphase spreads. This assay provides the most detailed analysis for measuring chromosome damage, but the laboriousness of enumerating the aberrations in metaphase spreads has prompted the development another assay which was the micronucleus (MN) assay.

Micronucleus in dividing cells can be originated from acentric fragments or whole chromosomes that are unable to travel to the spindle poles during mitosis. By telophase, a nuclear envelope is formed around the lagging chromosomes and fragments, which then uncoil and gradually assume the morphology of an interphase nucleus with the exception that they are smaller than the main nucleus in the cell; hence, they are called "micronuclei." MN, therefore, provide a convenient and reliable index of both chromosome breakage and chromosome loss. Because MN are expressed in cells that have completed nuclear division, they can be ideally scored during the binucleated stage of the cell cycle (Sinitsky & Druzhinin 2014). Here in this study the evaluation of micronucleus frequency in peripheral blood lymphocytes of Mamuju inhabitants

also conduct to ensure the cytogenetic effect of low radiation dose. Populations residing in HBRA are exposed to low radiation dose for generations, throughout their lives. The effect of low dose has important implications in radiation protection science. Studies of persons from HBRA provide an opportunity to understand better the biological effects of low-dose exposures. The effect of low dose exposure (<100 mSv) has important implications in radiation protection science (Karuppasamy et al. 2016).

Material and Methods

Blood Sampling

Seventy healthy adult subjects from Botteng and eighteen healthy adult subjects from normal background radiation area were included in this study. Peripheral blood samples were collected by venipuncture using heparinized vacutainer tubes (BD Vacutainer systems). The study was approved by Ethics Committee of the National Institute of Health Study and Development, Indonesian Ministry of Health, number LB.02.01/ 5.2.KE.051/2015 date of January 29, 2015. Informed consent was obtained from all donors. A detailed questionnaire was used to obtain information on age and occupation.

Chromosome Aberration Assay

Blood cultures were set up according to the IAEA standard procedures with minor modifications. One ml of whole blood samples were cultured for 48 hours in the incubator at 37°C containing 5% CO_2. The culture medium consisted of 7.5 ml of Rosewell Park Memorial Institute (RPMI) 1640 supplemented with 20% heat inactivated fetal bovine serum (FBS), 1% streptomycin/penicillin, 2.5% ml of phytohemagglutinin (PHA). Colchicine was added to the culture for the last 3 hours of culture at a final concentration of 0.05 µg/ml. The cells then were centrifuged for 10 minutes at 1500 rpm and re-suspended in 10 ml of 0.075 M KCl (pre-warmed to 37°C) for 25 minutes. The cells then were centrifuged again for 10 minutes at 1500 rpm and re-suspended in 2 ml of fresh fixative that was prepared from methanol and acetic acid (3:1). The fixation step was repeated four times until white sediment was obtained. The cell suspension then was stored in -20°C at least for one night until the slide preparation was conducted. Fixed cells were dropped onto clean, wet slides, dried and stained with 4% Giemsa solution (pH 6.8) for 10 minutes. The frequencies of unstable chromosome aberrations (dicentric, ring and acentric fragments) were scored in metaphase cells that contained complete 46 chromosomes. At least 200 metaphase cells for each donor were analyzed.

Micronucleus Assay

Micronucleus assay was conducted based on protocol in IAEA publication (Agency 2011). Whole blood samples were cultured for 72 hours in the incubator at 37°C containing 5% CO_2. The culture medium consisted of 4.5 mL of Rosewell Park Memorial Institute (RPMI) 1640 supplemented with 20% heat inactivated fetal bovine serum (FBS), 1% streptomycin/penicillin, 2.5% ml of phytohemagglutinin (PHA). Cytochalasin-B was added to the culture at 44 hours at a final concentration of 6 µg/ml. The cells then were centrifuged for 10 minutes at 1000 rpm and re-suspended in 7 ml of 0.075 M cold (4°C) KCl. The cells then were centrifuged again for 8 minutes at 1000 rpm and re-suspended in freshly made fixative consisting of methanol: acetic acid (10:1) diluted 1:1 with Ringer's solution. The cells then were washed with two to three further changes of freshly prepared fixative consisting of methanol: acetic acid (10:1) without Ringer's solution, until the cell suspension is clear. The cell suspension then was stored in -20°C at least for one night until the slide preparation was conducted. Fixed cells were dropped onto clean, wet slides, dried and stained with 4% Giemsa solution (pH 6.8) for 12 minutes. The slides then were analyzed based on Fenech (2007) publication. Two thousand binucleated lymphocytes were scored minimally at the magnification of 400× for each sample.

Dosimetry

The measurement of gamma ray exposure level was carried out using portable gamma spectrometer Exploranium GR-135 Plus. Outdoor radiation levels was measured using a portable plastic scintillometer (PM1405, Polimaster) measuring micro-Sievert per hour ($\mu Sv\ h^{-1}$), with an accuracy of ±10, calibrated using different radiation sources (from Environmental Survey Laboratory, Radioecologic Division, Center for Technology of Radiation Safety and Metrology, National Nuclear Energy Agency of Indonesia).

Statistical Analysis

Unpaired *t-test* was used to compare the total chromosomal aberrations and MN numbers between HBRA and control groups using SPSS 22.0 statistical software, if the data have a normal distribution. The Kolmogorov-Smirnov test was applied to know the distribution of data.

Results and Discussion

The results showed that from a total of 14,695 cells in average 209 cells per subject were analyzed in Botteng samples only five dicentrics chromosomes, four acentric fragments and three ring chromosomes were found. While in the control samples

from a total 4,000 cells that analyzed only one dicentric chromosome and four acentric fragments were found (Table 1). For micronucleus a total of 154,443 BNC were scored in 70 individuals from Botteng, where the mean MN numbers per binucleated cells were 44.25±13.78. In control group a total 39,866 BNC were scored in 18 individuals from NBRA, with the mean MN numbers per binucleated cells were 37.94± 10.59. A more detail results about MN numbers in Botteng and control samples are presented in Table 2. The mean age (mean±SD) of Botteng and control samples was 41±6.19 and 49.2±7.66 years, respect-tively. Our study showed that there were insignificant different in the mean of dicentric, ring and also MN numbers per binucleated cells between Botteng and control groups ($p > 0.05$). Interestingly the mean of dicentric, ring and also MN numbers per binucleated cells in Botteng area were higher compared to control. This finding was in a good agreement with Alatas et al. study in 2012 that also found a higher of mean dicentric and ring per cells in Botteng inhabitants compared to control.

Our study also revealed that linear regression analysis showed insignificant correlation between the MN numbers with age in all groups ($p = 0.588$; $p = 0.684$). Even though there was a tendency that MN numbers increase with age all groups (Figure 1 and 2). It has been reported that age and gender, either alone or in combination can significantly the MN frequency in lymphocytes (Karuppasamy et al. 2016). Several factors or the combination of each factor can increase the MNs linearly with age likes the cumulative effect of acquired mutations in genes involved in DNA repair, the numerical and structural aberrations in chromosomes caused by exposure to endogenous genotoxins, inadequate nutrition, exposure to environmental or occupational genotoxins, as well as a wide range of unhealthy lifestyle factors (Fenech & Bonassi 2011). Increase of MN frequency with age in this study possibly due to an increase in acentric fragments formed by unrepaired DNA strand-breaks induced either endogenously or by exposure to environmental clastogens or to an increasing number of spindle disturbances resulting in chromosome lagging at anaphase (Karuppasamy et al. 2016).

Table 1. The mean chromosomes aberrations and MN numbers of Botteng and control samples.

Group	Number of sample	Mean Age ± SD (Range, Years)	Mean Dic+Ring percells	Mean MN numbers per binucleated cells ± SD
HBRA	70	41 ± 16.19 (14 – 85)	0.00054	44.25 ± 13.78
Control	18	49.2 ± 17.66 (17 – 80)	0.00025	37.94 ± 10.59

Table 2. The distribution of MN numbers in Botteng and control samples.

Group	Age (Years)	n*	Mean Age± SD	Mean MN numbers per binucleated cells ± SD	MN Distribution				Total MN
					1MN	2MN	3MN	4MN	
HBRA	18 – 30	23	24.04 ± 4.98	42.69 ± 13.83	748	93	16	0	982
	31 – 40	14	35.5 ± 3.48	44.50 ± 17.82	441	63	16	2	623
	41 – 50	12	44.83 ± 2.72	41.58 ± 9.57	367	45	14	0	499
	> 50	21	61.04 ± 9.10	47.3 ± 13.05	728	112	14	0	994
Total		70			2284	313	60	2	3098
Control	18 – 30	4	23.75 ± 4.71	29 ± 8.86	80	15	2	0	116
	31 – 40	2	40 ± 0	42 ± 2.82	56	7	2	2	84
	41 – 50	2	46.5 ± 4.94	48 ± 21.21	62	10	2	2	96
	> 50	10	61.8 ± 9.73	38.7 ± 8.51	298	35	5	1	387
Total		18			496	67	11	5	683

***n :** number of sample

The mean MN numbers per BNC cells in females was higher compared to males in all groups (44.81 *vs* 43.68 in Mamuju and 38.33 *vs* 36.17 in control) (Table 3). Even though the different was not statistically significant ($p > 0.05$) our data was supported the assumption that MN frequency in females commonly higher compared to males. It was known that MNs frequency in females tends to be higher relative to males by a factor approximately 1.4. Studyer suspect that the higher of MNs frequency in female correlated with greater tendency of the inactive X-chromosome to be lost as an MNs relative to other chromosomes, and to the fact that females have two copies of the chromosome compa-red to only one in males (Fenech & Bonassi 2011; Nefic & Handzic 2013). A study conducted by Jones et al. in 2012 showed that in 19.9% of the cells scored at least one sex chromatin positive MNs was present. Other study by found that X-chromosome present in 72.2% of the MN scored and a significant increase with age in the number of MN containing an X-chromosome (Hando et al. 1994).

Conclusion

Here in this study the evaluation of chronic low radiation dose exposure using chromosomal aberration and MN assays showed that there was no significant effect on unstable chromosomal aberrations and MN numbers among Botteng inhabitants. As stated by Karuppasamy et al. in 2016 that the simplest explanation of the insignificant difference is the level of radiation exposure was not adequate to induced significant chromosomal aberrations in Botteng inhabitants. Another explanation is the repair process of the DNA damage in individuals from Botteng was very efficient. Further study to measure the DNA repair capacities of Botteng inhabitants could provide information to prove it.

Acknowledgment

The authors gratefully acknowledge Center for Technology of Radiation Safety and Metrology (PTKMR). This study was supported by grants from the National Nuclear Energy Agency of Indonesia (Badan Tenaga Nuklir Nasional) and conducted as a BATAN Annual Research Project in 2015.

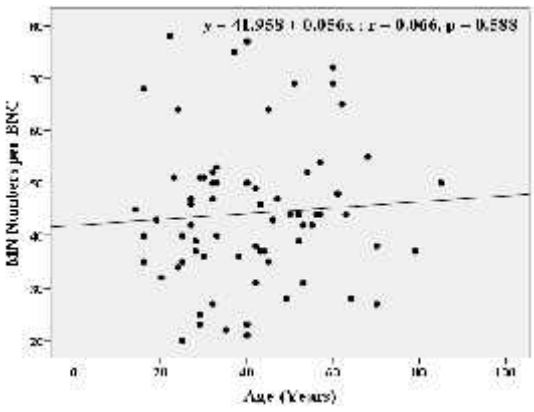

Fig 1. Regression analysis, correlation between of age and MN numbers per BNC in Botteng Area

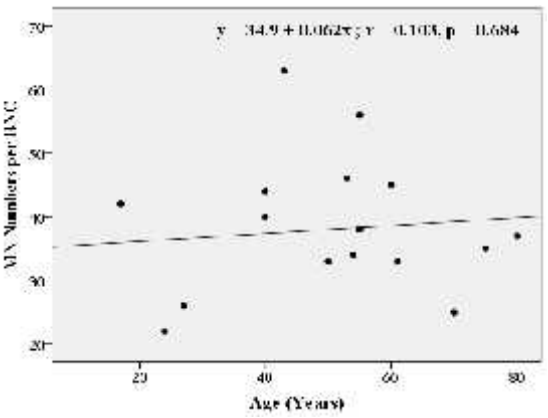

Fig 2. Regression analysis, correlation between of age and MN numbers per BNC in Control Area.

Table 3. The mean MN numbers in females and males from Mamuju (HBRA) and control samples.

Group	Gender	n*	Mean MN numbers per binucleated cells ± SD
HBRA	Females	34	44.81 ± 12.80
	Males	36	43.68 ± 14.91
Control	Females	12	38.83 ± 12.46
	Males	6	36.17 ± 5.81

***n : number of sample**

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