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Abstract. This paper reviews the properties, process and effect of ionizing radiation towards human health. The fetus and human embryo are much sensitive to ionizing radiation. The health consequences of exposure can be vary even at low radiation and as a result it will affect the mother. Such consequences can include cancer, malformations, growth retardation and impaired brain function. There are two types of biological effects which is deterministic and stochastic effect. Biological effect of radiation results from both direct and indirect action of radiation. Radiation exposure may be external or internal and can be acquired through various exposure pathways. Different organs have different sensitivity to ionizing radiation. Ionizing radiation is a radiation that carries enough energy to liberate electrons from atoms or molecules, thereby ionizing them. Ionizing radiation is made up of energetic subatomic particles, ions or atoms moving at high speeds such as alpha, beta, gamma, neutron particles and X-rays. The spontaneous disintegration of atoms is known as radioactivity and the excess energy emitted is a form of ionizing radiation. As the use of ionizing radiation increases, so does the potential for health hazards.

1. Fetus and Children

The tightly bound electron can be remove from an atom when the ionizing radiation have enough energy and ion will be creating when the ionizing radiation consist of particulate or electromagnetic energy [1]. For examples, alpha particle which cannot penetrate single layer of skin but beta particles can penetrate few millimeters of skin. Both alpha and beta particles, may act as carcinogens or initiate other adverse health effect when inhaled, ingested, or injected, but due to the to their lack of penetrating power both of the particles do not pose a significant to health threat [2]. When evaluating the effects of exposure during the pregnancy, it is important to considerate all the dose absorbed at the level of fetus especially potential teratogen whose dose dependent on the action [3].

The effect of the radiation is more towards the failure of embryo implantation, an early abortion or no other consequences after 14 days of conception [4-5]. From the end of the 2nd to the 8th week post-conception is the organogenesis period which the fetus is extremely sensitive to the teratogenic effect of ionizing radiation and particularly effect the central nervous system (CNS) [6-8]. In the 8th and 15th week of pregnancy, is a period in which the fetus is very radiosensitive. The neuronal stem cells are subject to a notable mitotic activity and a proliferation along the passage that goes from the ventricular and sub ventricular zones to the cerebral cortex [9]. After the 25th week the central nervous system becomes relatively radio resistant and major fetal malformations and functional anomalies highly improbable if the fetus is keep exposing to the ionizing radiation [10].

Another effects that can be seen if the fetus is expose to ionization radiation are pregnancy loss either abortion or stillbirth, congenital malformations (anatomical defects), neurobehavioral abnormalities

but having mental retardation and the fetal growth retardation [11]. For major birth defects in the embryo, a woman who begins pregnancy has a reproductive risk of 3% and 15% for miscarriage when expose to the ionizing radiation but depends on the family story or reproductive health [12].

1.1 **Cancer Risk**

Ionizing radiation results in production of free radicals and this will make the cell or tissue becomes oxidative stress and cause severe damage to cellular macromolecules and nuclear DNA and because of that, cancer disease will occur [13]. When the cell is exposed to high dose radiation, cell division is uncontrolled, cancer will occur and patient need to face with acute radiation sickness for examples, coagulopathy, diarrhea, immunity disorders, burns, fever , coordination and equilibrium disturbances [14].

Leukimia was the first cancer to be linked with the exposure of the radiation after two or three years of bombing in Hiroshima and Nagasaki, leukemia cancer is detected from the children to the adults with the highest number of people exposed [15]. Other than leukemia, breast, colon and lung are the other types of cancer which are reported with highest number of people but this disease are more exposed to the children than the adults [16].

The atomic bombs from the ionizing radiation are approximately at background levels and chronic lymphotic leukemia (CLL) risks in Japans as atomic bombs in Hiroshima and Nagasaki but CLL is more common in Europe [17]. Normally, chronic lymphotic leukemia (CLL) elevated with the persons with cancer prostate, uranium miners and cleanup workers in Chernobyl either the person exposed to the radiation or not. [18].

2. Deterministic and Stochastic Effect

Basically, deterministic effect can be defined as the radiation dose “determines” the effect. Other than determination effect from dose, there are several factors that influence the radiation effect such as total dose, volume of tissue irradiated, dose rate, type and quality of the radiation, concomitant physical trauma, presence of other disease conditions, and/or thermal burns, and individual susceptibility [19-22]. Deterministic effect occurs when large enough radiation dose applied and induced the death cell. This effect can impair the integrity and function of organ and tissue. The threshold dose is needed to be exceed before the radiation-induced damage [23]. The tissue will react when the dose higher than normal low dose. So, this proved that the effect can be seen after the threshold dose occurs. The more the dose, the more the severity effect due to dependent of severity to dose [24]

There are two reactions either earlier or late reaction effect. For the early level of the tissue reaction some of symptom may occur. Three mains categorized of the single exposure radiation syndrome included the hematopoietic, gastrointestinal, and central nervous (CNS) syndromes [25]. Hematopoietic syndrome is a syndrome that related to the bone marrow. Bone marrow is the one of highly metabolic site which can disturb when 0.20 Gy dose radiate on it. However, the changes not a clinical considerable until it dose in a range of 0.75 to 10 Gy [26]. Lymphocytes is one of bone marrow component product to our body. It has the large concern on radiosensitivity to the damage of radiation. Radiodermatitis is a term that describes skin effects of radiotherapy like skin ulceration [27]. Gastrointestinal symptom included haemorrhagic and diarrhoea [28]. The hematopoietic and gastrointestinal are caused by depletion of stem cell while for central nervous syndromes are mostly damage that caused by membrane damage. Meanwhile, for the long-term reaction it a continuous of the early reaction symptom like cataracts, cardiovascular disorder, necrosis and for extreme cases resulting death [29].

While, stochastic effect is a damage that occur on genetic material even in low dose radiation [30]. On the other word, stochastic is an ionizing-radiation induced mutations and occur commonly in rapidly and uncontrol dividing cells and in higher cancer risk organ and tissue structures such as bone marrow, breast, stomach, lung tissues and colon [32-33]. For both radiations induced cancer and heritable disease, the probability of the occurrence of the effect depends on the dose. The risk stochastic effects increases with dose, with no threshold. Stochastic effects expert panels have discoursed that the existing data best support a linear, no known threshold act a basis for radiation protection [34-38]. Stochastic effect usually occurs from delayed effect like cancer.

3. Physics of Ionizing Radiation

Ionizing radiation is defined as radiation with enough energy. During an interaction with an atom, it can remove tightly bound electron from the atom orbit then causing the atom to become charged or ionized. Ionizing radiation is divided into two types which are directly ionizing and indirectly ionizing. In directly ionizing radiation there are radiative sources such as alpha articles, beta particles, positrons and charged nuclei while indirectly ionizing consists of photon radiation and neutron radiation that is electrically neutral and could not interact with matter.

The most common ionizing radiation is called alpha radiation. It is a particle that is exist in the atom's nucleus. Alpha radiation occurs when the atom undergoes radioactive decay, it kicks off a particle called alpha that consists of two protons and two neutrons. Alpha particles are very heavy. When it interacts with matter it can only travel a few centimetres. The properties of alpha radiation are that it could not penetrate the outer layer of dead skin cells since it can be stopped by using a piece of paper only.

Meanwhile, beta radiation is in the form of either an electron or positron. Positron has the same size and mass as electron but with positive charge. It is also a particle that is emitted from an atom when interacted with high energy. Beta particles have slightly lower mass than alpha thus it can travel further in the air and can even penetrate the skin. Hence, it gives a little bit danger towards human. However, it still can be stopped by using thick piece of plastic or aluminium. If an individual is exposed to beta radiation it may gave some external health risks to his or her body.

For indirect ionizing radiation there are two major types of radiation that gave effects as ionizing radiation which are gamma and neutron radiations. Gamma radiation does not exist in the form of particle as alpha and beta, instead it is a form of energy that is being emitted from an unstable nucleus. Its properties are having no mass and neutral thus it can travel much farther in the air compared to alpha and beta. Since it has high characteristic in penetrating the matter it can only be stopped by using a thick or dense enough material such as lead and concrete. This type of materials are the most effective ways to become the shielding objects from the radiation. Gamma radiation if exposed towards human may lead to tremendous health risks and could also cause fatal.

4. Conclusion

The hazard of radiation on human health is well known since previous century. It can cause biological effects, particularly change of molecules within the cell. Radiation is proven to have a carcinogen effect but is less associated to genetic effects.

Acknowledgement
The authors would like to thank the Applied Physics Programme, Faculty of Applied Sciences and Technology Universiti Tun Hussein Onn Malaysia for facilities provided and gratefully acknowledged the financial support a research grant (H074) that make the research possible.

References

[1] US Environmental Protection Agency (EPA). Radiation: non-ionizing and ionizing. Understanding radiation.
[2] Oak Ridge Institute for Science and Education (ORISE). The medical aspects of radiation incidents. Oak Ridge, TN: Oak Ridge Institute for Science and Education, US Department of Energy; 2011.
[3] Santis, M. De et al. 2005. "Ionizing Radiations in Pregnancy and Teratogenesis A Review of Literature." 20:323–29.
[4] ICRP Publication 73. Radiological protection and safety in medicine. Ann ICRP 1997;26:1–3
[5] Jankowski CB. Radiation and pregnancy. Putting the risks in proportion. Am J Nurs 1986;86(3):260
[6] Brent RL. Utilization of developmental basic science principles in the evaluation of reproductive risks from pre- and postconception environmental radiation exposures. Teratology 1999;59(4):182–204.

[7] Moore NW, Adams CE, Rowson LE. Developmental potential of single blastomeres of the rabbit egg. J Reprod Fertil 1968;17(3):527–31.
[8] Willadsen SM. A method for culture of micromanipulated sheep embryos and its use to produce monozygotic twins. Nature 1979;277(5694):298–300.
[9] Mole RH. Detriment in humans after irradiation in utero. Int J Radiat Biol 1991;60(3):561–4.
[10] International Commission on Radiological Protection. 1990 Recommendations of the International Commission on Radiological Protection. Ann ICRP 1991;21(1–3):1–201.
[11] Brent R. Saving lives and changing family histories: appropriate counseling of pregnant women and men and women of reproductive age, concerning the risk of diagnostic radiation exposure before and during pregnancy. Am J Obstetrics Gynecol 2009;200(1):4–24.
[12] Ray, Kausik. 2017. "Toxicity of Radiation : Biological Effects of Ionizing Radiation Exposure on Reproduction." 359–75.
[13] Wu, L.J., Randers-Pehrson, G., Xu, A., et al., 1999. Targeted cytoplasmic irradiation with alpha particles induces mutations in mammalian cells. Proc. Natl. Acad. Sci. U.S.A. 96, 4959e4964.
[14] Valentin J. ICRP publication 105: radiological protection in medicine. Ottawa: International Commission on Radiological Protection; 2007.
[15] IARC, Ionizing radiation, Part I: X- and gamma radiation and neutrons, vol. 75, Lyon, International Agency for Research on Cancer (IARC) Monographs on the Evaluation of Carcinogenic Risks to Humans), 2000.
[16] K. Kodama, F. Kasagi, Y. Shimizu, N. Nishi, M. Soda, A. Suyama, T. Okubo, Long term health consequences of atomic bomb radiation RERF, life span study, Int. Congress Ser. 1299 (2007) 73–80.
[17] D.L. Preston, S. Kusumi, M. Tomonaga, S. Izumi, E. Ron, A. Kuramoto, et al.,Cancer incidence in atomic bomb survivors Part III. Leukemia, lymphoma andmultiple myeloma, 1950–1987, Radiat. Res. 137 (1994) S68–S97.
[18] E.C. van den Broek, L. Liu, E.F. Posthuma, M.L. Janssen-Heijnen, J.W. Coebergh,I. Soerjomataram, Increased risk of chronic lymphocytic leukaemia amongcancer survivors in the Netherlands: increased detection, causal factors orboth, Ann. Hematol. 93 (2014) 157–162.
[19]Christensen, D. M., Iddins, C. J., & Sugarman, S. L. (2014). Ionizing Radiation Injuries and Illnesses. Emergency Medicine Clinics of NA, 32(1), 245–265.
[20] Wakeford, R. (2015). From Hiroshima and Nagasaki to Fukushima 1 Long-term eff ects of radiation exposure on health. *The Lancet*, *386*(9992), 469–478.
[21] Abdelkarim, A., & Jerrold, L. (2018). Clinical considerations and potential liability associated with the use of ionizing radiation in orthodontics. American Journal of Orthodontics and Dentofacial Orthopedics, 154(1), 15–25.
[22]Fry, A. (1990). Health Effects of Ionizing Radiation, (2), 475–488.
[23] Greenberg, B., Herbert, A. S., & Justino, H. (2017). SC. JACC: Cardiovascular Imaging. Elsevier Inc. https://doi.org/10.1016/j.jcmg.2017.04.003.
[24]Elizabeth, A., Stephen, A. A., Scott, B., Dalke, C., Jarrin, M., Kunze, Hamada, N. (2016). Ionizing radiation induced cataracts: Recent biological and mechanistic developments and perspectives for future research. Mutation Research-Reviews in Mutation Research.
[25]International Commission on Radiological Protection. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP publication 103. Ann ICRP 2007; 37(2–4):1–332.
[26]Ismail, A. H., & Jaafar, M. S. (2011). Interaction of low-intensity nuclear radiation dose with the human blood : Using the new technique of CR-39NTDs for an in vitro study. *Applied Radiation and Isotopes*, *69*(3), 559–566.
[27] Bs, A. M., Downing, T. E., Ms, X. Z., Ryan, R., Cctn, R. N., Rossano, W., & Msce, A. C. G. (2014). Author â€TM s Accepted Manuscript. Journal of Heart and Lung Transplantation
[28]Gerber TC, Carr JJ, Arai AE, et al. Ionizing radiation in cardiac imaging: A Science advisory from the American Heart Association committee on cardiac imaging of the council on clinical cardiology and committee on cardiovascular imaging and intervention of the council on cardiovascular radiology and intervention. Circulation 2009;119:1056-1065.
[29]Groen, R. S., Bae, J. Y., & Lim, K. J. (2012). Fear of the unknown : ionizing radiation exposure during pregnancy. YMOB, 206(6), 456–462.
[30]Hill, K. D., Frush, D. P., Han, B. K., Abbott, B. G., Armstrong, A. K., Dekemp, R. A., … Viswanathan, M. N. (2017). Radiation Safety in Children With, 10(7).

[31]Brown KR, Rzucidlo ER. Acute and chronic radiation injury. J Vasc Surg 2011;53:15-21S.

[32]Sancaktutar, A. A., Silay, M. S., Bodakci, M. N., & Atar, M. (2013). Endourology and Stones Knowledge and Attitude of European Urology Residents About Ionizing Radiation €.

[33]Zhou GZ, Wong DD, Nguyen LK, et al. Student and intern awareness of ionising radiation exposure from common diagnostic imaging procedures. J Med Imaging Radiat Oncol. 2010; 54:17-23.

[34]Berrington de Gonzalez A, Darby S. Risk of cancer from diagnostic X-rays: estimates for the UK and 14 other countries. Lancet. 2004; 363:345-351.

[35] Lagarón, J.-M. (2011). *Multifunctional and nanoreinforced polymers for food packaging*. Cambridge: Woodhead Publishing Materials.

[36] Ozdemir, M., Yurteri, C.U., & Sadikoglu, H. (1999). Surface treatment of food packaging polymers by plasmas. *Food Technol.*, *53*, 54-58.

[37] Schneider, J., Akbar, M.I., Dutroncy, J., Kiesler, D., Leins, M., Schulz, A., Walker, M., Schumacher, U., & Stroth, U. (2009). Silicon oxide barrier coatings deposited on polymer materials for applications in food packaging industry. *Plasma Process. Polym.*, *6*, S700-S704.

[38] Poncin-Epaillard, F., Chevet, B., & Brosse, J.-C. (1994), Reactivity of a polypropylene surface modified in a nitrogen plasma. *J. Adhes. Sci. Technol.*, *8*(4), 455-468.