Effect of Ionizing Radiation Towards Human Health: A Review

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Abstract. This paper reviews the properties, process and effect of ionizing radiation towards human health. 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. Unstable elements which disintegrate and emit ionizing radiation are called radionuclides. It has many beneficial applications, including uses in medicine, industry, agriculture and research. As the use of ionizing radiation increases, so does the potential for health hazards. Radiation exposure may be internal or external, and can be acquired through various exposure pathways. Different organs have different sensitivity to ionizing radiation. Understanding the effects of radiation on human bodies provide useful information for the development of radiation protection measures.

1.0 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 because of ionizing radiation is a 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 generation 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, immunity disorders, diarrhea, fever, burns, 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].

2.0 Deterministic 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, dose rate, volume of tissue irradiated, type and quality of the radiation, presence of other disease conditions, concomitant physical trauma 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]. At lower levels of exposure such acute effects are not observed but the probability of the late health effects can be significantly increased.

2.1 Stochastic Effect

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 breast, bone marrow, stomach, colon and lung tissues [32-33].

Mutations in single cells may eventually lead to serious consequences. If the mutations occur in somatic cells and involve modifications in genes related to the formation or prevention of malignant, certain types of cancers may develop in the tissue or organs of the exposed individual. However, mutations in germ cells, related with transmitting genetic information to the descendants of the exposed individual, it is possible that hereditary disorders may rise [34].

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 [35]. Stochastic effect usually occurs from delayed effect like cancer.

The risk of ionizing radiation exposure from medical imaging cannot be negligible. This due to the linear relationship between the stochastic effects of radiation exposure and cancer development [36]. A

significant increase in cancer cases are shown in some report that state up to 430 new cases of cancer per year in Australia could be attributed to diagnostic radiation even absolute risk to an individual may be small, the exposure of large numbers of people over time and repeated exposure to individual patients have an addition [37-38]

3.0 Physics of Ionizing Radiation

Ionizing radiation is defined as radiation with enough energy so that during an interaction with an atom, it can remove tightly bound electron from the orbit of an atom, 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 nucleus of an atom. 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 thus, when it interacts with matter it can only travel a few centimetres in air. 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.

3.1 Application of Ionizing Radiation

Ionizing radiation has been used widely among food industries, pharmaceuticals, cosmetics and in sterilization process to help improve the quality of the products produced. The most common field that applies the ionizing radiation is by food packaging. Food packaging is crucial in protecting the foodstuffs for the period of processing, storage and distribution from infection by dirt, microorganisms, parasites, and toxic materials as well as preventing any factors that may affect colour, smell and taste of the products [39]. Food packaging is mostly made from plastics. The widely used types of plastics are polyethylene (PE) polymers, polypropylene (PP), polystyrene (PS), poly (ethylene terephthalate) (PET) and poly (lactic acid) (PLA).

There are lots of types of ionizing radiation application that are being used in industries to improve the functionality of food packaging. The first one is gamma radiation. By exposing gamma radiation onto the food packaging allowing the attachment of functional groups on a surface lead to halt enzymes or other bioactive species [40]. Gamma irradiation is well known for its advantages of being non-polluting and giving effects at ambient temperature. It involves energetic gamma photons specifically for sterilization.

Ionizing radiation also could be used for cold plasma or also known as plasma exposure. It is involving energetic neutrals such as atoms and molecular components, ions, radicals, photons and electrons. During this process, it modifies the surface of the packaging without altering the bulk properties and it

allows a wide range of surface modifications which enhancing the quality of the food packaging. This is due to the plasma that can contain various energetic and reactive moieties such as free radicals, ions, electrons and molecules which could interact with the surface of the material. The result of this application is the longer the plasma treatment, the higher the free radical concentration is obtained.

Electron beam irradiation is another application of ionizing radiation. Compatible with its name, it uses electron sources as the initiator of the bombardment. To improve the functionality of the packages a highly directional ions of variable energy is being used. It portrays degradation effects on the surface of the polymers and also disproportionation which produces chain scissioning and gas evolution.

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