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Exposure to Ionizing Radiation and Radiological Implications: a review of ICRP, IAEA and UNSCEAR recommendations.

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ABSTRACT

All living organisms are continually exposed to ionizing radiation which has always existed naturally. Human activities involving the use of radiation and radioactive substances cause radiation exposure in addition to the natural exposure. This exposure is associated with several undesirable health effects. In view of this; individuals, corporate organizations, and various governmental bodies are to take responsibility of reducing exposure to radiation in the environment. This paper presents a review of the publications of three international recognized bodies on the sources of radiation; studies, associated health risk and radiological implications.

KEY WORDS: *ionizing radiation, sources of radiation, health effects, radiological implication,*

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I. INTRODUCTION

Man is continuously exposed to ionizing radiation from Natural Occurring Radioactive Materials (NORM) which is present in various degrees in all media in the environment including the human body itself. All the three natural radioactive chains are accompanied with emission of alpha particle, beta particles and gamma photons which is their primary source. The gaseous radon members of the three chains are radioactive alpha particle emitters. For many years, radon was recognized as constituting a hazard to underground miners. An increased risk of lung cancer associated with exposure to radon and its decay products is well established from epidemiological studies of underground miners. However, from residential radon studies, it was also recognized that domestic exposure to radon might carry a risk, the potential risks to tissues and organs other than the lung are of great interest.

Ionizing radiation represents electromagnetic waves and particles that can ionize, i.e. remove an electron from an atom or molecule of the medium through which they propagate. Ionizing radiation may be emitted in the process of natural decay of some unstable nuclei or following excitation of atoms and their nuclei in nuclear reactors, cyclotrons, x-ray machines or other instruments. For historical reasons, the photon (electromagnetic) component of ionizing radiation emitted by the excited nucleus is termed gamma rays and that emitted from machines is termed x-rays. The charged particles emitted from the nucleus are referred to as alpha particles (helium nuclei) and beta particles (electrons). [1]

While so many researches are on gamma dose rates in soils and radon concentrations in mines in some part of the world, there still exist sparse knowledge on these from indoor home environment and workplaces such as schools, offices, shops, churches and outdoor environment such as fields, gardens, parks e.t.c in many part of the world today. Majority of people spend 80 % of their time indoor and 20 % outdoor which exposes them to radiations, thereby need for monitoring. While some countries have action guidelines and rules for radiological control others have very limited awareness of this. There is need to conduct nationwide survey in order to have detailed data bank on radiation exposure.

The human exposure pathways to radiation are external and internal [2] The external exposure pathway may be through the source of radiation to atmospheric or water body to soil or sediment or building surface or vegetation to human while the internal exposure pathway may be through the source of radionuclides to atmosphere or water body to soil or sediment to vegetation, marine foods, inhalation of resuspended radionuclides or ingestion of radionuclides in foods or beverages. The importance of the various exposure pathways depends on: (a) The radiological properties of the material released (e.g. gamma emitters, beta emitters or alpha emitters; physical half-life) (b) The physical (e.g. gas, liquid or solid) and chemical (e.g. organic or inorganic form, oxidation state, speciation, etc.) properties of the material and its migration characteristics; (c) The dispersal mechanism and factors affecting it (e.g. stack height, meteorological conditions, etc.) and environmental characteristics (e.g. climate, type of biota, agricultural production, etc.); (d) The locations, ages, diets and habits of the exposed individuals or population [2].

II. SOURCES OF RADIATION

All living organisms are continually exposed to ionizing radiation which has always existed naturally. The sources of this exposure are cosmic rays that come from outer space and from the surface of the sun, terrestrial radionuclides that occur in the earth's crust, in building materials, air, water, foods, and in the human body itself. Some of these exposures are fairly constant and uniform for all individuals everywhere, for example the dose from ingestion of potassium-40 in foods. Other exposures vary widely depending on location: for example, cosmic rays are more intense at higher altitudes, and concentrations of uranium and thorium in soils are elevated in localized areas. Exposures can also vary as a result of human activities and practices [1]. The intensity of the gamma radiation from the ground depends on the concentration of the radioactive substances in the soil, rocks and soil cover. The same applies to the radon contents of soil air and subsoil water. More than 90% of the gamma radiation above the ground originates in the uppermost 20 cm of the soil layer. The water in the pores of the soil and the vegetation cover provides shielding from gamma radiation, to some extent.

Human activities involving the use of radiation and radioactive substances cause radiation exposure in addition to the natural exposure. Some of these activities simply enhance the exposure from natural radiation sources. Examples are the mining and use of ores containing naturally radioactive substances and the production of energy by burning coal that contains these substances. Environmental contamination with radioactive residues from nuclear weapons testing continues to be a global source of human radiation exposure. Each nuclear test resulted in unrestrained release to the environment of substantial quantities of radioactive materials. These were widely dispersed in the atmosphere and deposited everywhere on the earth's surface. The production of nuclear materials for military purposes has left a legacy of large amounts of radioactive residues in some parts of the world. Nuclear power plants and other nuclear installations release radioactive materials into the environment and produce radioactive waste during operation and on their decommissioning. Specific individuals residing near installations releasing radioactive material into the environment may be subject to higher exposures. The use of radioactive materials in industry, agriculture and research is expanding around the globe, and people have been harmed by mishandled radiation sources [1]. The medical use of radiation is the largest, and a growing, man-made source of radiation exposure. It includes diagnostic radiology, radiotherapy, nuclear medicine, and interventional radiology. Radiation exposure also occurs as a result of occupational activities. It is incurred by workers in industry, medicine and research using radiation or radioactive substances [1]

The dose to humans from gamma radiation from natural radioactive elements originates partly from the ground and partly from building materials. High radon concentrations can be found in buildings in areas with alum shale and uranium-rich granites and in soils that have high permeability, for example gravel and coarse sand. In unsaturated soils or rocks, radon moves with air through pores and fractures; in saturated zones, radon moves with groundwater to underground openings, such as mines, caves and to buildings. When water-containing radon is used in a household, more than 50% of the radon reaches the indoor air. The radon emission from the water contributes to the radon concentration of the air but it is seldom the cause of high indoor concentrations. Radon in the indoor air emanates by diffusion from ground surface and building materials. Radon is not only a problem in dwellings, considerate amount of gamma dose can be found in indoor and outdoor environment in homes and workplaces. In homes, underground mines, and situations where ventilation is limited, the levels of these radionuclides and their decay products can accumulate to high levels.

III. RADON AND GAMMA RADIATION STUDIES

Substantial compilations of radon measurements appeared in the UNSCEAR 2000, 1993, and 1998 reports [3, 4and 5]. A national survey carried out in the United Kingdom in the early 1980s provided results of gamma dose rate and radon concentration measurements in more than 2000 dwellings. The mean radon levels was 20.5 Bq/m^3 and in regions with elevated uranium mineralization survey showed average radon levels up to 300 Bq/m^3 for areas of south-west England which are about 15 times the national average [6]. The influence of groundwater on radon concentration in drinking water and subsequent on residential radon levels in air from the use of portable water indoors was also investigated in radon-prone areas of Japan [7, 8and 9]. A study of indoor and outdoor radon levels in Brazil reported that variability in radon levels of about 50 % in a single day could be measured on an hourly basis, with the highest values in the morning and lowest value in the afternoon. Also reported was a seasonal variability of two orders of magnitude in outdoor levels with the highest in the dry winter season and the lowest levels in the wet summer months [10].

In Nigeria; gamma dose rate exposure levels in building materials were measured in Ibadan metropolis, the calculated annual effective dose for indoor and outdoor for floor tiles were 0.520 ±0.01 mSv and 0.46 ± 0.01 mSv, for wall tiles 0.42±0.01 mSv and 0.37±0.02 mSv and for water closet 0.36±0.01 mSv and 0.333±0.02 mSv [11]. Likewise in a survey of 34 points across three institutions in Minna, dose rate range from 0.125 µSv/h to 0.171 µSv/h at Niger State College of Education, at the Federal University of Technology, Bosso, between 0.152 µSv/h and 0.184 µSv/h and at the Federal University of Technology, Gidankwano between 0.137 µSv/h and 0.184 µSv/h, annual effective dose obtained is 0.189 mSv/y [12]. In a related measurement of 24 indoor and outdoor ambient radiation levels in Keffi, the mean annual indoor and outdoor annual equivalent dose rates were computed as 1.08 ± 0.04 mSv/y [13]. Investigation of natural gamma radioactivity levels in surface soil in Ore metropolis, Ondo State, reported the annual effective dose rates to vary from 18.91±1.35 to 50.27± 1.69 µSv/y [14].

In Cyprus urban areas, a total of 20 indoor and 70 outdoor in situ measurements were performed, the calculated gamma effective dose rate range from 78 to 319 µSv/y with a mean value of 138± µSv/y. the indoor/outdoor dose ratio was found to be 1.4±0.5 [15]. A 259 indoor and outdoor in situ gamma spectrometry measurements was performed in Greek urban areas, the mean total outdoor and indoor absorbed dose rate in air ranges between 22 and 108 nGy/h and 26 – 83 nGy/h respectively [16]. Activity concentration of ^{232}Th, ^{226}Ra and ^{40}K varies between 4.5-45 BgKg^{-1}, 4.9-160 BgKg^{-1} and 190-2029 BgKg^{-1} respectively in indoor environment covered with Brazilian granites. The external gamma-ray dose rate was 120 nGy/h, while radon concentration in room ventilated adequately (0.5h^{-1}) will be lower than 100 Bq/m^3 [17]. In the study of indoor ^{222}Rn concentrations in different classes in Faculty of Science, Jazan University, about 46 % of concentration of radon was higher than the recommended level and 54 % was below [18]. Studying the variation of radon levels in some houses in Alexandria city, Egypt, radon concentrations and annual effective dose varied from (38.62 to 120.39) Bqm^{-3} and (0.96 to 3.06) mSvy^{-1} [19]. Kitchens and bathrooms have high radon content compared to other compartments of the same dwelling.

Strand et al. reported radon measurements performed in 3,660 day-care centers in Norway, the arithmetic mean radon concentration is 88 Bq/m^3, the geometric mean 45 Bq/ m^3 and the maximum 2,800 Bq/m^3 [20]. In natural radioactivity measurements in the Nordic countries, estimated average effective dose (mSvyr^{-1}) in gamma radiation from bedrock, soil, and building material are in Finland 0.5, Sweden 0.5, Denmark 0.3, Norway 0.5 Iceland 0.2; radon concentrations at home and at work Finland 2.0, Sweden 1.9, Denmark 1.0, Norway 1.7 and Iceland 0.2 mSvyr^{-1} respectively [21] Higher gamma radiation is found in some places in Sweden, Norway and Finland, mainly in connection with pegmatite rocks, alum shale and mineralization of uranium and thorium [21]. Summary of reports on concentrations of radon in indoor air for about 76 countries was presented in the UNSCEAR 2006 reports [22]. It is not possible to present surveys results from radon and gamma dose rates measurements for all countries but some are noteworthy.

IV. SYSTEM OF RADIOLOGICAL PROTECTION

Approaches to protection against ionizing radiation are remarkably consistent throughout the world. This is due largely to the existence of a well established and internationally recognized framework. The UNSCEAR regularly reviews the natural and artificial sources of radiation in the environment to which people are exposed, the radiation exposure due to those sources and the risk associated with that exposure. It reports its findings to the United Nations general assembly on an ongoing basis. The ICRP is a non governmental scientific organization which has regularly published recommendations for protection against ionizing radiation. The IAEA has a statutory function to establish safety standards, where appropriate with collaboration with other relevant international organizations. The recommended investigation level for indoor radon in existing dwellings has been set to 200 Bq/m3 while the action level for radon in existing dwellings and aboveground workplaces is 400 Bq/m3, in underground workplaces within the interval 400 – 1,500 Bq/m^3 and an annual effective dose of 1 mSv/yr for the members of the public in exposure to gamma radiation [23].

V. GENERAL PRINCIPLE OF RADIOLOGICAL PROTECTION

Radiological protection has the general aim of protecting humans and the environment from harm from ionizing radiation after external and internal exposure. To achieve this International recommendations and regulations varying from countries to countries has been put in place to monitor and control exposure to ionizing radiation**.** For all human activities that add to radiation exposure or practices. ICRP recommends a system of radiological protection based on three central requirements:

Justification of a Practice: No practice involving exposure to radiation should be adopted unless it produces at least sufficient benefit to the exposed individual or to society to offset the radiation detriment it causes.

Optimization of Protection: In relation to any particular source or radiation within a practice, the dose to any individual from that source should be below an appropriate dose constraint and all reasonable steps should be taken to adjust the protection so that exposure are "as low as reasonable achievable". Economic and social factor being taken into account

Application of Individual Dose Limits: A limit should be applied to the dose received by any individual on the result of all the practices other than medical diagnosis or treatment to which he /she is exposed.

In some cases, as for example after an accident that releases radioactive material to the environment or when high indoor levels of radon occurs, It may be necessary to intervene to reduce the exposure of people, ICRP recommends a system of radiological protection for intervention based on two other principles:

Justification of Intervention: The proposed intervention should do more good than harm, that is, the benefit resulting from the reduction in dose should be sufficient to justify the harm and the costs, including social cost of the intervention

Optimization of Protection: The form, scale and duration of the intervention should be chosen so that the net benefit of the reduction of dose, that is, the benefit of reduction of in dose less the costs of the intervention, should be as large as reasonably achievable [23].

VI. IONIZATION IN TISSUE

Each time charged particles ionizes or excite an atom, it loses energy until it no longer has enough energy to interact, and all the energy deposited in biological tissues by ionizing radiation is eventually dissipated as heat through increased vibration of the atomic and molecular structures. It is the initial ionization and the resulting chemical changes that cause harmful biological effect. A most important property of the various type of ionizing radiation is their ability to penetrate matter. The depth of penetration for a particular type of radiation increases with its energy but varies from one type of radiation to another for the same amount of energy. With charged particle such as alpha and beta particle, the depth of penetration also depends on the mass and charge of the particle. For equal energies a beta particle will penetrate to a much greater depth than an alpha particle. Alpha particle can scarcely penetrate the dead, outer layer of human skin; consequently radionuclides that emit them are not hazardous unless taking into the body through eating, breathing or a skin wound. Beta particles penetrate a few centimeters of tissues, but not to internal organs, so radionuclides that emit them are hazardous to superficial tissues but not to internal organs unless they too are taken into the body. For indirectly ionizing radiation such as gamma ray and neutrons, the degree of interaction depends on the nature of their interactions with tissues. Gamma ray can pass through the body so radionuclides that emit them may be hazardous on the outside or inside [23]

VII. EFFECTS OF RADIATION ON CELLS

The gross effects resulting from exposure to radiation is caused by ionization and excitation of relatively few molecules in the cell of an absorber. The building unit of every living matter is the cell. It consists of the nucleus and the cytoplasm. All metabolic activities are carried out in the cytoplasm under the guidance of the nucleus [24]. The cells most significant content is nuclei acid and chromosomes. The two nuclei acids found in the nucleus of the cell are Ribonucleic Acid (RNA) and Deoxyribonucleic Acid (DNA). The RNA is responsible for protein synthesis. The chromosomes are composed of genes and genes are made up of DNA. The DNA molecule contains the genetic code of each species.

Radiation effects are caused by the damage inflicted on cells by the radiation interactions. The damage may result in cell death or modifications that can affect normal functioning of organs and tissues. Most organs and tissues of the body are not affected by the loss of even considerable numbers of cells. However, if the number lost becomes large, there will be observable harm to the organ or tissue and therefore to the individual. Only if the radiation dose is large enough to kill a large number of cells will this harm occur. This type of harm occurs in all individuals who receive an acute dose in excess of the threshold for the effect and is called deterministic (acute).

It occurs only if the radiation dose is substantial such as in accidents. If the cell is not killed but only modified by the radiation damage, the damage in the viable cell is usually repaired. If this repair is not perfect, the modification will be transmitted to daughter cells and may eventually lead to cancer in the tissue or organ of the exposed individual. If the cells are concerned with transmitting genetic information to the descendants of the exposed individual, hereditary disorders may arise. These effects in the individuals or in their descendants are called stochastic; cancer and hereditary effects and may be caused by damage in a single cell. As the dose to the tissue increases from a low level, more and more cells are damaged and the probability of stochastic effects occurring increases.

Radiation damage to the cell may cause the chromosome or DNA molecule to break either by direct action or indirect action. In the direct action, radiation hits the DNA molecule directly disrupting the molecular structure. The structural change leads to cell damage or even cell death. Direct action of radiation by ionizing and excitation may occur anywhere in the body. In the indirect action, water constitutes about 80 % of the cell mass the other 20 % being complex biological compounds[23] when ionizing radiation passes through cellular tissues it produces charged water molecules, these break up into entities called free radicals that are chemically toxic which may produce new chemical compounds unhealthy for the organism. Damage to DNA in the nucleus is the main initiating event by which radiation causes long-term harm to organs and tissues of the body. Double-strand breaks in DNA are regarded as the most likely candidate for causing critical damage. Single radiation tracks have the potential to cause double-strand breaks and in the absence of 100% efficient repair could result in long-term damage, even at the lowest doses [23]

VIII. CONCLUSIONS

Ionizing radiation occurs naturally with sources from cosmic rays, terrestrial radionuclides and human activities. Though several researches have taken place to measure radiation levels or dose rates in the environment in many countries but the fact still remains that many countries are still naïve on this issue. Several researchers based their standard on the proposed UNSCEAR policy whereas environmental condition and so many other factors differ from one country to other; this is inevitable since their host country is either nonchalant to the aspect of radiological protection or have limited awareness of this. In other to grease the effort all International organizations such as ICRP, IAEA, UNSCEAR and make their work beneficial to all and sundry, awareness should be created to the members of the pubic, stakeholders and government of each country necessitating them to be on their toes to set radiological protection guidelines and put in place a solid environmental radiation monitoring programme to reduce radiation exposure to the environment and the public.

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