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Review Paper

Radioactivity and Its Possible Impact on Environment and Human Health: A Review

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Abstract

All environmental components consist of an extensive amount of radioactivity despite of various geographical location and geological differences. Radioactivity is found in rocks, soil, air, water, building materials, foods etc. Natural radioactivity (^{232}Th, ^{40}K) that radiates from natural resources is the main contributor to the exposure of biota. Along with that, anthropogenic radionuclides (^{137}Cs, ^{134}Cs, ^{90}Sr) also have a significant role to external exposure impact and human health effect. This paper reviews the theoretical interpretation of radioactive pollution when it exceeds permissible unit. The radioactivity concentration of radionuclides above the threshold level is detrimental to human health as well as environmental components. Swift dividing cells of mammals are the most vulnerable and generally experience the maximum consequential damage from acute exposure (bone marrow, lymphatic tissue). Cellular damage of DNA may occur towards high levels of radiation exposure that results in cancer, genetic deformation of genes, cardiovascular disorder and in some cases death. Thus, the understanding of the contribution of radioactive material present in the surrounding plays a beneficiary role in radiation protection. As gamma radiation is emitted from primordial radionuclides and has a high penetration capacity, gamma-ray spectrometry system is used for the measurement of radioactivity.

Keywords: Radioactivity; exposure; impact; environment; human health.

Introduction

Radioactive elements have always existed from the time of the evolutionary period of the Earth. The environment & its people obtain some level of radiation perpetually from both the natural and anthropogenic sources which may release alpha, beta and gamma rays; that is contemporary in our terrestrial, aquatic and atmospheric environment. All people comprise of internal radiation mainly from radioactive potassium-40 (internal irradiation of food) and carbon-14 which they had inside their bodies from birth. Moreover, cosmic rays from outer space, building material can radiate a certain extent of radiation which might not be harmful for human when present at trace amount. In addition, exposures can also get deviated by the consequences of human behavior and practices such as X-rays, Gamma rays used in scientific research and medical application[1]. Identification and assessment of radioactive pollutants in the domain is not sufficient to precisely detect their influence. Besides, it is indispensable to diagnose their consequences on biotic structures, which is the end point of toxicant-induced impairment[2]. Among all the radionuclides, exposure of Radon can cause lung cancers among human and is called the principal natural initiator of human irradiation. Except that, thorium, potassium, radium also has the ability to affect the human body by cancer, anemia, leukemia, pericarditis, sterility, pneumonitis through ingestion, inhalation and organ exposure[3]. Not only these radioactive materials have negative consequences on human health, they also have major influence on the environment and the ecosystem. Moderate to high level exposure of radiation dose to conifer trees are enough to cause mortality, productivity reduction and sterility[4]. Apart from that, dark spot on leaves, dried tips of the leaves, photosynthesis obstruction are also detected[5]. Among animal kingdom, mammals and birds are more radiosensitive species and display sign of impaired fertility, infertility, reduction in sperm cell count or fertility-related parameters like offspring number and size, deformities in embryos due to radioactivity[6]. Thus, radioactivity handicaps the standard of life and health of biota based on exposure rate and duration.

Background Study of Radioactivity

Radionuclide: Radionuclides can have similar atomic number but different mass number. Excess number neutrons or protons in the nucleus leads to unstable nuclei because of the force became unbalanced in between them. The nature of unstable nuclei is to breakdown incessantly until it reaches to a stable point where it's no longer a part of a radioactive decay. In this process, the nucleus spontaneously disintegrates into alpha (α), beta (β), gamma (γ) particles and Electromagnetic waves (X and c-rays) with a certain level of energy, is called radioactivity[3]. As it mentioned earlier, besides naturally occurring radionuclides, it could be detected from artificial sources like nuclear reactor and radionuclide generators. There are about 730 radionuclides which generally have longer than 60 minutes half-lives. Among them, 32 radionuclides are primordial that were generated in evolutionary period[7]. The deleterious effect of a radionuclide depends on the duration of their half-life. Elevated half-life of radionuclide tend to have less impact on human and ecosystem and radionuclides with a short half-life constitute a profound risk damage in human health. As radionuclides generally have extended half-life, they can persist for a prolonged period of time in the environment and transfer into different isotopes by breaking down incessantly[1,3,8]. Table-1 discusses about some of the common radionuclides and their impacts on human health.

Table-1: Impact of radionuclides[3].

Radionuclide	Half-Life	Impact
Caesium -137	30 year	Accumulates in muscle tissue, possesses risk of cancer
Plutonium -238	87.7 years	Mostly affects lungs, bronchia, liver and bone marrow immediately
Strontium -90	28.8 years	Absorbed into the bones of small children, large doses replace calcium in the bones and cause chronic renal failure, bone deformity and tumors.
Uranium -235	703.8 million years	Can cause bone and lung cancer. Internal organ could be damaged if exposed to higher concentration.
Radium -226	1.599 years	Exposure to higher levels can cause cancer, anemia, cataracts and fractured teeth.
Thorium -229	7.340 years	Causes abnormality in chromosome and mutagenesis leads to metastasized condition.
Radon (Rn)	3.7 days	The second leading cause of lung cancer is Radon exposure. Also, can cause lung diseases like pulmonary fibrosis, emphysema, and chronic interstitial pneumonia.

Radiosensitivity: Organisms have their own physical and morphological characteristics against the radioactivity. Based on these characteristics to lethal effects of radiation, they are called radio sensitive or radio tolerant species. Depending on the inter-phase chromosomal ratio of sensitive cells a traditional classification has been formulated recently. Some experimental researches declare mammal is the most radio sensitive species. Plants exhibit a vast range of delicacy against radiation and display symptoms like early morbidity and reduced germination capacity. Mosses, lichens, algae and micro-organisms (bacteria, viruses) are the most radio tolerant to acute radiation exposure compared to other living things. Considering this facts, radiosensitivity is higher in consumer level and tends to be lower in producer level of a food chain. Thus it may follow this sequence -Mammals > Birds > Fishes > Insects > Trees > Mosses > Lichen > Algae > Micro-organisms. The life stages of organisms control an enormous part to measure sensitivity to radiation. Adults tend to be more adaptive and radio tolerant towards radiation than embryos and juvenile forms[9].

Sources of Radiation: Natural Radiation: Natural radiation can emit from cosmic ray, atmosphere, food, soil and also from building materials. Biological system of Earth is exposed to natural radiation but as long as it is in the tolerable limit, the consequences remain invisible. All people comprise of some internal radiation from birth which mainly comes from radioactive potassium-40 and carbon-14 and can be the reason of exposure to others. Cosmic ray is a cause of natural radiation which travels through the space with a very high speed but Earth's magnetic field resist the harmful wave. Though, a small amount of cosmic radiation enters the surface of the Earth through its high penetration capacity. Variation in radiation doses from cosmic rays differentiate with altitude and latitude. Thus, radiation becomes more intense towards the poles[10].

7% of Earth's total radiation emits from the sun which tends to lie in the Ultraviolet range (200–400nm). The composition of the UV radiation gets reconstructed while travelling through the stratosphere and finally the total flux that reaches on the Earth got consequentially compacted. While infiltrating the Earth, atmospheric gases absorb the shortest wavelength of UV-C rays (200– 280nm), the ozone cover incorporate the UV-B rays (280– 320nm. On the other hand, ozone layer is completely unable to absorb UV-A radiation (320–400nm) and the most harmful for biota. Some unabsorbed UV-B rays also reach Earth's surface and can cause significant threats for all living organisms after UV-C rays[11].

Thoron and Radon gas may present in the atmosphere from the break-down of Uranium and Thorium and release contain alpha, beta and gamma rays. Foods that are digested by humans are also not free from radioactivity. Internal irradiation of food causes from the trace of Potassium-40 which is dispersed in both soil and water and incorporated by plant and other organism. Moreover, building material is extracted from the ground and emits gamma rays relentlessly. Sometimes occupational exposure to excessive natural radiation can be fatal. In that manner, humans are exposed to both indoor and outdoor environments[10].

Clinical Radiation: Detection, diagnosis and treatment of diseases through numerous processes may release various radioactive elements that can be detrimental towards human health. X rays and Gamma rays are ionizing radiation used in nuclear medicine, radiation therapy, CT scan, fluoroscopy, mammography, radiography, and proton therapy. In the medical procedure, X-ray is used to diagnose the disease towards which patients are the most exposed to radiation. Many Radioactive isotopes like iodine-13 used in thyroid diagnosis and technetium-99 requires in radioactive imaging procedure as a tracer. Some non-ionizing radiations are used for MRI (Magnetic Resonance Imaging), ultrasonography, echocardiography, anesthesiology and urology[1].

Nuclear Radiation: Nuclear Power Plants require Radioactive materials like Uranium and Plutonium require in a nuclear power plant to originate a chain reaction that produce energy which runs the turbines for the production of electricity. It also releases a slight amount of radioactive waste to the adjoining environment by maintaining proper jurisdiction. But this radioactive waste further gets deposited into the soil and sediments in water and initiate radioactivity in the adjacent environment[1]. Lack of thoroughly supervision, two principal liquid by-products (Tritium and Strontium-90) can be easily produced. Tritium is a radioactive isotope of hydrogen that has the ability to elevate the risk of cancer development in soft tissues. It can contaminate the water and inhibit the natural growth of aquatic life. On the other hand, Calcium gets relocated by Strontium-90 because of the same valence electron. After ingestion, it is deposited in teeth and bones which may amplify the risk of bone cancer and leukemia in people[12].

Impacts on Environment

High radiation exposure can influence not only humans but also other part of the environment like animals, plants, invertebrates adversely due to various level of sensitivity. Impacts of radioactivity on environment are quantified from the dose response relationship between individuals, which shows the state of a total population. Radiation doses delivered over 5days to 60 days can affect various soil invertebrates, algae, mosses and other plant communities. Minimum level of exposure can originate mutagenesis which changes the physiology of an offspring and reproduction capacity and other minor effects. Change in species composition, alteration in species diversity through the rate of mortality asserts the intermediate effects of radiation. Massive mortality of individuals unveils the sign of severe effects[13]. Here, Figure-1 interprets the level of biological damage in the environment according to the applied dosage.

Impacts on Flora: Among plant kingdom, trees seem to be more radiosensitive compared to shrubs and herbs. In the plant species, chronic irradiation starts at the dose rates of 1000 to 3000 micrograys per hour and less than 400 micro grays per hour (10 milligray per day) displays negligible impact based on sensitivity[9]. Moreover, mosses, liverworts and lichens tend to be more radio resistant because of their cellular and molecular characteristics that help them to support radiation stress. Dormancy or growth rate and other processes related to seasonal change can initiate alteration in sensitivity[15].

Many researches showed that, conifers and pines show early signs of radioactive stress. Moderate to high level of exposure to conifer trees are enough to cause mortality, reduction in productivity and sterility[4]. Apart from that, photosynthesis inhibition, reduction in transpiration rate and metabolite synthesis, dead spots on leaves, dried leaf tips are also detected[5]. As for pine tree, if dose rate can exceeds 20Gy, it is sufficient to cause death[16]. The first sign for the detection of the radiation injury is yellowing reactor and needle death, which may appear between 2-3 weeks after exposure. Disturbed growth in meri-stem tissue, reduced trunk width, dwarf shoots or needle, extreme needle growth, deformation in orientation are some common signs that is observed in moderate dose (5-15 Gy) exposure. Seeds from these effected trees tend to have low germination capacity[17]. High dose exposure can result to the death of all coniferous and pine trees in the vicinity and may undergo community shift by grass, shrubs and young deciduous species[18]. Radioactive material can damage tissue as well as DNA which can cause mutation. DNA is highly sensitive towards natural irradiation (UV-B) to cause photo transformation. Elevation of the natural radiation has effect on plant growth, morphology and physiology and plant tend to respond differently according to the fluctuation of natural radiation. Inversion of DNA sequence (TCAG converted to GACT) and chromosome structure deformation can inhibit the normal growth of a plant[19]. Plants grown in higher altitude generally are more radiation tolerant than plants in lower altitudes on account of radiation exposure levels[20,21]. Table-2 summarizes the discussed impact on flora based on radiation doses.

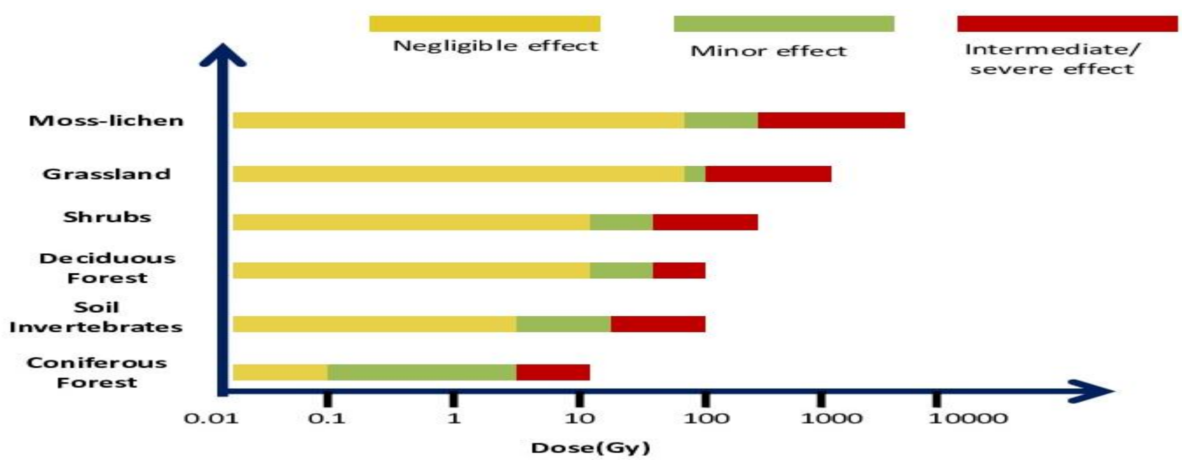

Figure-1: Range of short term acute radiation doses that produced biological damage[14].

Table-2: Impacts on flora based on radiation exposure.

Dose	Impacts	References
>5 Gy	Yellowing reactor and needle death	17
5-15 Gy	Disturbed growth in meri-stem tissue, reduced trunk width, dwarf shoots or needle, extreme needle growth, deformation in orientation, low germination capacity of seeds	17
>20 Gy	Deaths, inversion of DNA sequence, community shifts by radio resistant species	18

Impacts on Fauna: Vertebrate animals and insects remain safe from natural radiation by their external body layer like feathers and fur[20]. Radiation affected vicinity include soil and fluvial environment act as the ultimate sink of radioactive particle, which can impact the invertebrate present in the litter layer. Larvae and nymphs are less likely to be present in the litter layer due reduced reproduction rate. Doses greater than 30 Gy reported to have catastrophic impact on invertebrate community consisting of death of embryos and zygotes in early life and miscarriages in adults[22]. But compared to other vertebrates amphibians are much exposed to natural radiation[20].

According to IAEA (2006), mammals are the most radiosensitive organism and exposure to radiation might affect reproduction rate more than their mortality rate. Experiment shows, at 3Gy mortality rate and at 0.3 Gy reproduction rate is affected. Thus, it might show some acute impact at dose rates of 400 microgray[9]. Altered reproductive capacity for higher level exposure is demonstrated for various kind of animal like goats, cows, pigs, donkeys, dogs, rabbits, sheep, monkeys and found reduction of thyroid activity, lowered body temperature, oedema (fluid retention), heavy breathing, impaired fertility, infertility, reduction in sperm cell count or fertility-related parameters like offspring number & size, deformities in embryos due to radiation exposure. In some cases, prolonged exposure to natural UV radiation creates distortion in mammal immune system. Histological and biochemical mechanisms that include changes in Langerhans cells in skin, possible DNA damage, variation in antigen response can also be spotted[6].

Plankton and benthos from aquatic environment can also face various degrees of alteration from contaminated sediments and nuclear waste from power plants[23]. Natural radiation (UV-B) also has detrimental effect in aquatic species like bacterioplankton and phytoplankton which includes early mortality, reduced growth and productivity[6]. But among aquatic organisms, fishes are less radio tolerant species. Malignant consequences can be seen with elevating dose rate and at 1mGy they seem to unveil visible symptoms[24]. During gametogenesis and embryo development stages they become most sensitive. This hindrance can be resolved by the mobilization capacity from moving high exposure area to low exposure areas which is not available for stationary soil invertebrates. So, stationary soil invertebrates tend to obtain significant doses of exposure relative to the other organisms of the animal kingdom[25].

For birds like barn swallow, reduced reproductive rate is unable to support stable population can be the reason of making this specific species vulnerable or threatened. Consequential increase in abnormal sperm, antioxidant reduction in blood and liver was also observed due to exposed radiation[26]. Table-3 summarizes the impact on fauna based on exposure level.

Impacts on Ecology and Biodiversity: Radioecological impact is generally measured with the relation of transferred radionuclides into the environment and the adverse impact of radioactivity on biota. Radioactive materials are constantly breaking and releasing free particles into the atmosphere which finally ends up in either soil or water, called the sink of radionuclides. Radionuclides penetrates deep into the soil can obstruct the growth and reproduction of organisms present in litter and top soil[11]. Radionuclides with longer half-lives can create a particular problem for the organism. Plants that are exposed to natural radiation modify themselves frequently and interact with other plants and consumer organisms[20,25]. They remain in the soil and water for a long time and large number of plants consume it and thus they invade the food chain by biomagnifications. In the aquatic ecosystem, contaminated sediment and underwater plants uptake the radionuclide and it circulates to the plankton and benthos through bioaccumulation process. But aquatic habitat tends to be more tolerant of radioactive contamination than terrestrial habitat. Not only the physical visible damage can occurred in the ecosystem but also long-term biological impact can hinder the population. Genetic mutations could be a potential threat to maintaining the biodiversity[27].

Impacts on Human Health

Radioactive particles primarily interact with cells and tissues of human body through damaged skin, digestive and respiratory system, exceeding tolerance level of received dose. Mild symptoms are visible with the dose of 30 rads. With the expansion of dose rate, duration and total dose the probability of measurable effects increases as well. Another important factor in measuring radiation is the parts of the body exposed to radiation[28].

Tissue and Cellular DNA: From the study, it has been found that the organ which consists of slowly dividing cells (muscle, bone, liver, kidney, lungs) is often classified as radio resistant. On the contrary, rapidly proliferating cells of the bone marrow, the germinal cells present in testis and in skin, stomach and intestine epithelial cells; all classified as radiosensitive[29,30]. The severity of injury is detected through the ability of repopulation after the radiation exposure[31,32]. Injury will be repairable if the rate of functional cell after exposure falls below condemning level. It generally takes several weeks for the repairment of the tissue. The damage status will be measured by health condition, dose and duration also tolerance extent of tissue which will declare the minority or severity of the impact[33]. However, it is highly unlikely of the rate of damage to be dependent on the size rather than the cell kinetics of the tissue. That's why, cell death and depletion present more in rapidly diving tissues (gastrointestine, testis) and less in slowly dividing tissues (kidneys, lungs)[34].

Nuclear radiation generally ionizes particular cells and causes harm. Among them, gamma radiation told to be the most dangerous as it can ionize the water molecule and its ion might react with DNA to rupture it while passing through a cell. Low doses of background radiation for a long time might cause permanent damage to cells but might repair the damage incorrectly which will further lead to genetic mutation. At high doses of radiation, cells might continue to produce abnormal cells which maybe cancerous and sometimes tissues fail to function anymore[28]. Breaking of DNA double-strand (DSBs) is noted to be highly accountable for the demise of cells due to radiation induced cellular DNA effect till date. Various genetic diseases are leading to radiosensitivity, immunodeficiency and sometimes cancer-proneness caused by DSB repair impairments[35].

Reproduction: Except from the exposure to natural radiation, impact on reproductive organ may come from repercussion from medical treatment and consequences of therapeutic irradiation and intentional research exposure. Radiation tends to have a significant effect on reproductive function that generally depends on total dose, duration and any fracture present on various tissues and organs. Gonads are highly radiosensitive organs that have resultant or permanent effects on fertility[39]. As a consequence, adults may experience fluctuation or deficiency in sex hormone and under ages may suffer from pubertal dysfunction. As for central nervous system, hypothalamic-pituitary axis is related to the occurrence of puberty, hormone distribution etc. So, cranial irradiation might display the symptoms of early of late puberty, lack of sex hormone, excessive flow of prolactin hormone. Although it affects both the male and female similarly but females seem to be more vulnerable at lower radiation doses which may cause due to received treatment of lymphoblastic leukemia[36-38]. Exposure to abdominal, pelvic, spinal or testicular radiation may cause infertility and impaired sex steroid reduction. However, premature labor, premature babies, low sperm count, genetic mutation, abnormal growth of baby, miscarriages, problematic pregnancy due to proper expansion of uterus, ovarian dysfunction, endocrine dysfunctions are also reported as a result of irradiation[39].

Mutagenesis: Mutations are changes in DNA structure that can happen different ways but two major foundations are irradiation and chemical mutagens. Among ionizing and non-ionizing radiation, ionizing radiation tend to have more harmful consequences as it radiates high energy than non-ionizing radiation. Ionizing radiation attacks normal atoms and causes them to break into ions and free radicals. These charged free particles then strike the covalent bond present in nucleotide linkage in DNA strand. As a result, DNA breaks into many small parts, which the cells try to recover by themselves. In most of the cases, the cells recover the DNA pieces incorrectly and change the DNA sequence which creates mutagenesis[40]. Mutations are two types one is substitutions and another is frame shift mutations. Substitution is the replacement of one base by another and frame shift mutations include either extra nucleotides or remove one or more nucleotides. This operation can lead to produce cancer cells like Leukemia and Thyroid Cancer[41]. Except that, genetic diseases due to single cell inheritance are cystic fibrosis, sickle cell anemia, marfan syndrome; due to multifactorial genetic inheritance are Alzheimer's disease, arthritis etc can also happen in case of doubling the dose[42].

Cardiovascular and Neurological Disorder: Apart from natural radiation, medical technologies also have impact on the human cardiovascular and neurological system in terms of treatments.

Table-3: Impacts on fauna based on exposure level.

Fauna	Dose	Impacts	References
Mammals	.3Gy->3Gy	Altered reproductive capacity, reduction of thyroid activity, lowered body temperature, oedema (fluid retention), heavy breathing, impaired fertility, infertility, distortion in immune system, changes in Langerhans cells in skin, possible DNA damage, variation in antigen response	6,9
Fishes	1mGy	Most sensitive in gametogenesis and embryo development stages, early mortality, reduced growth and productivity	24
Birds	-	Reduced reproductive rate, consequential increase in abnormal sperm, antioxidant reduction in blood and liver	26
Invertebrate	>30Gy	death of embryos and zygotes in early life and miscarriages in adults	6

Radiation therapy is a popular method for treatments for the removal of tumor and cancer which is used with the compilation of high energy (more than 30–35 Gy) that leads to radiation induced heart diseases, problems in circulatory system and creates cardiotoxicity[43]. According to current literatures, there are three proposed mechanisms of Cardiovascular Diseases due to induced radiation. First one is ischemia which may originate from severe dysfunction of capillary networks. Second one is anatomical destruction of the arteries present in heart and last one is continual response of inflammation which is attributed to transcription factor that regulates genes responsible for immune response[44]. Radiation may induce a series of heart disease which includes pericarditis (tissue inflammation of the heart),premature coronary artery disease, heart valve disease, arrhythmia (heart rhythm transformation), atherosclerosis, cardiomyopathy (enlarged heart), congestive heart failure (loss of heart pumping ability), and cardiac conduction abnormality[45]. Most significant cause of death due to radiation therapy is coronary lesions[46].

Due to heavy radiation exposure, combination of various cells in hippocampal network may be the reason of alteration in synaptic protein levels, complexity of dendrites etc. [47]. Radiation research declared the considered safe dose of acute exposure is 0.1 Gy[48]. According to studies, neurogenesis get inhibited by the radiation through amount of dosage (>2 Gy to 45 Gy) and through parent cell and neural stem radiosensitive population got damaged in the brain[49]. This procedure blocks the new cell generation and causes neuroinflammation[50]. Low dose exposure of radiation tends to initiate the redox balance alteration by elevating the reactive oxygen and species of nitrogen in the Central Nervous System (Limoli 2004). Apart from that, exposure of high dose generally has miscellaneous impact on brain and cognitive function and hampers the ability to memorizing and learning. It can also damage the other regulatory systems indirectly which is being generated by Central Nervous System[51, 52]. Both acute and chronic exposure can change the function of Central Nervous System that further lead to the death of a cell by protein abrasion, oxidative stress and mitochondrial injury which cause neurological disease[53]. Besides that, dysfunctional or misfolded proteins can be the initiator of Alzheimer's or Parkinson's disease which can stimulate stress response pathways to remove the clustered proteins[54]. The impact of radiation in the central nervous system are highly significant noticeable in children than in adults and may have learning incapacities and cognitive disabilities[28].

Respiratory and Gastrointestinal Disorder: Inhalation of radionuclides in the normal environment of exceeding dose in the exposed individual can also initiate respiratory disease due to ionizing radiation. Generally, lungs are radiosensitive and thus can't withstand large doses of radiation due to its regenerative capacity. Based on total dose exposure, volume of irradiated portion radionuclides can cause severe damages that may lead to impaired oxygenation and reduced circulation potential[55].

Acute effects of radiation in the respiratory system can be divided into two syndromes. One is radiation pneumonitis which is a sensitivity response that eventually leads to chronic fibrotic reaction. Both acute and chronic phase can result in deaths (develops within 6 months after exposure to doses 8 Gy of X - or gamma rays). The damage occurred in radiation pneumonitis principally related to impaired endothelial cells that causing capillary leakage both interstitially and onto the alveolar surface. Other one is radiation fibrosis which takes about 6 months to years to develop after exposure of more than 20-30 Gy doses. Moreover, radiation induced pulmonary cancer is very common for mine workers as they are likely to exposed to radiation than normal people[34,55-57].

People may suffer from abdominal pain, bloating, rectal bleeding, diarrhea, steatorrhea, neutritional deficiencies, weight loss, small bowel obstruction, ulcer, severe gastritis after receiving therapy for abdominal or pelvic cancers might be from the radiation[58]. It also can hamper the patient's life standard by genitourinary disease and sexual dysfunction. After a long period of radiation exposure (6 months to 3 years) radiation enteropathy may show chronic impact on health [59, 60]. However, vascular sclerosis, intestinal epithelial mucosal atrophy can be occurred only after 3 months of exposure called the delayed effects. All these impact can result in terminal dysfunction in rectum and ileum, slow to heavy bleeding through the rectum, malabsorption etc.[58,61]. Table-4 reflects the studied impact on human health based on radiation exposure and dosage.

However, without any impairment human body may absorb up to 200 rads acutely. When the biological system is exposed about 50% of the people are expected to die within 60 days of the exposure. On the other hand, if within a short time total body dose remains higher than 600 rads, it is called fatal[28].

Radiation safety and Recommendation

Radiation safety procedure aims to bind the excessive exposure of radiation. But for the best protection, ALARA (as low as reasonably achievable) principle must be followed for time, distance and shielding while handling radioactive constituents. As for time, the less duration of exposure bring less fatality. Distance is inversely related to the radiation exposure. Even, higher amount of radiation exposure is less harmful if distance from the source remains greater than being present in the close radius of radiation source. Protective gear should be mandatory for the people who handle radioactive materials of a daily basis for medical or scientific purpose. Through justification, optimization and limitation radiation protection should be maintained thoroughly to avoid accidental and occupational exposure[74].

To maintain radiation protection, necessary knowledge of radiation impact and safety is the first and foremost responsibility. Some recommendations on the knowledge distribution pattern is discussed below:

i. To relay the message of the adverse impact on radiation to common people, internet blog or cartoon with hidden meaning can be posted on a daily basis to gain the interest of them to perceive more. ii. For reducing occupational hazard, training program or seminar should be arranged after every three months to remind and practice to avoid radiation exposure. iii. To aware the students about radioactivity, writing competition or Olympiad can be arranged centrally with prize money. iv. To increase the children's interest on radiation, theme costume gathering could be arranged based on "Chernobyl Disaster" or "Fukushima Accident".

Table-4: Radiation induced human health effect according to exposure & dosage.

Disease	Health Effects	Dosage (Gy)	Exposure	Rate of Effected People (%)	Ref.
Cellular	Inhibition of Cell Division	>2-3	-	-	62
	Apotosis, Cellular Disintegration	>10	-	-	62
Reproductive	Sterility, Permanent Menopause	20	6 weeks	50	63
	Incomplete pubertal development	20-30	4-6 weeks (in childhood)	70	64
	Pubertal Failure	>30	4-6 weeks (in childhood)	~7	21
	Miscarriage	>24	-	40	21
	Azospermia	30 (Over 20 Fraction)	4 weeks (in childhood)	80	64
	Reduced Sperm Count	3-9 (Over 20 Fraction)	4 weeks (in childhood)	80	64
	Low Testosterone Response	24 (Over 12 Fractions	3 weeks (in childhood)	80	65
Cardiovascular	Pericarditis	>30	12 months	20	44
	Cardiomyopathy	>60	-	10	66, 67
	Valvular Heart Disease	>40	-	12.4	68
	Fatal Ischemic Heart Disease	~43	5 weeks	-	69
		~50	2 weeks	-	
Neurological	Acute Brain Injury	20-40	-	-	70
	Metastatic Brain Tumor	50-60	-	-	71
	Endocrinopathy, Cognitive impairment, Necrosis	>50-60	6 months (in several fraction)	-	
Respiratory	Acute Pneumonitis	>8-10	6 months	-	34
	Pulmonary Fibrosis	>20-30	6 months–1 year	-	
Gastrointestinal	Ulcers	~40	>5 weeks	~4	72
		>50	>5 weeks	~16	
	Small Bowel Obstruction	~40	>5 weeks	~2	73
		>50	>5 weeks	~14	

Conclusion

This study ponders the speculative elucidation of radioactive pollution. Radiological impacts on biota are an indispensable concept of research on account of incessant reorientation of radionuclides and their long-term repercussions on genetic deformity that fall out through the off spring. From next generation DNA sequencing project, it is found that, 8.5-17% is inherited mutation. Natural radiation can't be avoided but to avoid artificial radiation exposure, radiation protection through ALARA (as low as reasonably Achievable) principle might come in handy. However, the knowledge distribution about radioactivity is the important part of radiation safety. Through competent training and seminar, common people could manage occupational exposure with the help of knowledge and practice. Successive supervision of radioactive ramification could be a constructive appliance in case of subsequent consequence diminution. For protection, restoration and preservation of our environment, health and lifestyle, the adequate knowledge of radiation footprint is inevitable.

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