

Impacts and Controlling Measures for Radionuclides

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Abstract Scientific research studies declared that in a short span of time, there will be severe environmental and human health hazards may occur due to radioactive chemicals. Living organisms' exposure to either low level or high level radiation may cause deep impact on their survival. It disturbs our living environment and does not allow further generations to lead healthy lives. Radiation effects human health in various ways, such as skin burns and acute radiation syndrome (Radiation sickness). It can also result in long term health effects such as cancer and cardiovascular disease. Though the impact of radiation is in low level, that causes gradual health disorders and leads to cancer risk. So, in the present paper I would like to study on radiation, its impacts on environment and human health in various ways, hazards of radiation, and controlling measures.

Keywords: radiation, impact, human health, environment, hazards

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1. Introduction

Natural sources of ionizing radiation include cosmic rays and Nucleiodes such as Potassium-40, Carbon-14 and Isotopes of Thorium and Uranium which are present in rocks, earth and building materials. Industrial sources of radiation include nuclear reactors, X-ray radiography, electron microscopy, X-ray diffractions, thickness gauges, smoke detectors, electron beam welding and certain processes. Including chemical analysis polymer curing, chemical/biological tracing, food and medical sterilization and mining, the radiation source can be sealed, when the radiation can be switched off or unsealed.

2. Sources of Ionizing Radiation

Ionizing radiation enters our lives in a variety of ways. It arises from natural processes such as, the decay of uranium in the earth and from artificial processes like use of X-rays in medicine. So Ionizing radiation sources are two types. One is natural source and the other is industrial or artificial source.

(i) Naturally occurring radioactive materials:

The cosmic rays, gamma rays from the earth, Radon decay products in the air and various radioactive nuclides found naturally in food and drink.

(ii) Artificially occurring radioactive materials:

Medical X-rays fallout from the testing of nuclear weapons in the atmosphere, discharge of radioactive waste from the nuclear industry, industrial gamma rays and miscellaneous items such as consumer products.

3. Various Types of Radiation

The nature of the radioactive decay is characteristic of the element; it can be used to 'fingerprint' the substance. Decay continues until both the original element and its daughter isotopes are non-radioactive. The half life, i.e. the time taken for half of an element's atoms to become non-radioactive, varies from millions of years for some elements to fractions of a second for others.

- i) **α -Particles** (helium nuclei, that is 2 Neutrons + 2 Protons): on emission of the original isotope degrades into an element of two atomic numbers or less, e.g. Uranium-238 produces Thorium-234. Such transformations are usually accompanied by γ -radiation or x-radiation. α - particles have a velocity above one tenth that of light within a range in air of 3-9 cm. Because of their relatively large size and double positive charge they do not penetrate matter very readily and are stopped by paper, cellophane, aluminum foil and even skin. If inhaled or ingested, however, absorption of α -particles within tissues may cause intense local ionization.
- ii) **β -Rays** comprise electrons of velocity approaching that of light with a range of several metres and an energy of 0-4 MeV. β -particles of <0.07MeV do not penetrate the epidermis whereas those >2.5MeV penetrate 1-2 cm of soft tissue. Thus β -emitters pose both an internal and an external radiation hazard: skin burns and malignancies may result. Once inside the body they are extremely harmful, though less so than γ -rays. About 1mm of aluminum is needed to stop these particles. Most β -emissions are accompanied by γ - or X-radiation

and result in transformation into the element of one atomic number higher or lower but with the same atomic mass.

- iii) **γ -Radiation** is similar to, but shorter in wavelength than X-rays and is associated with many α - or β -radiations. Radiation does not transform isotopes. Like X-rays, γ -rays are very penetrating. They are capable of penetrating the whole body and thus require heavy shielding. E.g. γ -rays from ^{60}Co penetrate 15 cm steel.
- iv) **X-Radiation** like γ -radiation is electromagnetic in nature. It can be emitted when β -particles react with atoms. More often it is electrically generated by accelerating electrons in a vacuum tube. The later source can be switched off. X-Rays are extremely penetrating and are merely attenuated by distance and shielding.
- v) **Neutron Radiation** is emitted in fission and generally not spontaneously, although a few heavy radionuclides. Eg. Plutonium undergoes spontaneous fission. More often it results from bombarding beryllium atoms with an α -emitter. Neutron radiation decays into protons and electrons with a half-life of about 12min and is extremely penetrating.

The same type of radiation emitted by different isotopes may differ significantly in energy e.g. γ -radiation from potassium-42 has about four times the energy of γ – radiation from gold-198. Units of radiation are the Becquerel (Bq), the grey (Gy) and the sievert (Sv).

4. Hazards

In the chemistry the hazards of radioactive elements parallel those of their isotopes. However the radiation poses additional toxicity hazards qualitative classification of selected isotopes in terms of toxicity is given in Table 1.

Table 1. Classification of isotopes according to relative radio toxicity per unit activity

Very high toxicity	Sr-90 + γ -90, *Pb-210 + Bi-210(Ra D +E), Po-210, At-211, Ra-226 +55 Percent*daughter products, AC-227,*U-233, Pu-239, *Am-241, Cm-242.
High toxicity	Ca-45,*Fe-59, Sr-89,Y-91,Ru-106+*Rh-106,*I-131,*Ba-140+La-140, Ce-144 + *Pr- 144, Sm-151,*Eu-154,*Tm-170, *Th-234 + *Pa-234,*natural Uranium.
Moderate toxicity	* Na-22,*Na-24, P-32, S-35, Cl-36,*K-42,*Sc-46, Sc-47, *Sc-48,*V-48,*Mn-52,*Mn-54,*Mn-56, Fe-55, *Co-58, *Co-60, Ni-59,*Cu-64,*Zn-65,*Ga-72, *As-74,*As-76,*Br-82,*Br-82,*Rb-86,*Zr-95 + *Nb- 95, *Nb-95,*Mo-99, Tc-98,*Rh-105, Pd-103 + Rh-103,*Ag-105, Ag-111, Cd-109 + *Ag-109,*Sn-113,*Te-127,*Te-129,*I-132,I- 132, Cs-137 + *Ba-137,*La-140, Pr-143, Pm-147,*Ho-166,*Lu-177,*Ta-18, *W-181,*Re-183,*Ir-190,*Ir-192, Pt-191,*Pt-193,*Au- 196,*Au-198,*Au-199, Tl-20, Tl-202, Tl-204,*Pb-203.
Slight toxicity	H-3,*Be-7, C-14, F-18,*Cr-51, Ge-71,*Tl-201.

The biological effects of ionizing radiation stem mainly from damage to individual cells following ionization of water content. Oxidizing species, e.g. H_2O_2 , form together with ions and free radicals all capable of chemical

attraction on important organic moieties within the cells. E.g. Nucleic Acids. Biological effects are influenced by the type of radiation, the dose, and duration of exposure, exposed organ and route of entry. Effects on cells include death, mutation and delayed reproduction. Acute adverse effects of exposure are illustrated in Table 2.

Table 2. Effects of acute exposures to X-and γ -radiation

Dose (Gy)	Effects
<1	No clinical effects but small depletions in normal white cells count and in Platelets likely within 2 days.
1	About 15% of those exposed show symptoms of loss of appetite, nausea, vomiting, fatigue etc.1 Gy delivered to whole body or 5 Gy delivered to Bone Marrow produces leukemia
2	Some fatalities occur.
3.5-4	LD ₅₀ , death occurring within 30 days. Erythema (reddening of skin) within 3 weeks
7-10	LD ₁₀₀ , death occurring within 10 days.

5. Impacts of Radionuclides on Environment

The release of radionuclide's and their persistence in the environment lead to long term external irradiation or internal contamination via the food chain or of drinking water for population living in the contaminated areas. Lack of knowledge on the effects of radionuclides endangers living environment and lead to environmental contamination. A few incidents like Hiroshima and Nagasaki who suffered acute exposure at high dose levels acknowledged that the molecular cellular and tissue processes triggered by chronic exposure. The international body known as the United Nations Scientific Committee (UNSC) on the effects of atomic radiation had drawn a review on the effects of ionizing radiation on the environment. In the committee for the first time issued a report which contained a review on effects of ionizing radiation on plants and animals. The review contained some findings on the changing nature of the scientific community's assessment of radiation's potential environment effects the plants, animals and other living organisms as part of the environment become dispersed due to the impact of radio nuclides.

Detrimental effects on the environment also have been observed in many areas as a consequence of plants and animals have been received short term, very high radiation doses which follow major accidental releases of radionuclide's for example an explosion in a nuclear reactor at the Chernobyl power plant on 26 April 1986 caused the release of substantial quantities of radionuclides during a period of 10 days. Airborne material was dispersed throughout Europe from the site in Ukraine. As the contaminated air spread throughout Europe and beyond, local weather conditions largely determined where the radionuclides were total rainfall caused more radionuclides to be deposited in some areas rather than others. The accident had a catastrophic effect locally and high radiation exposures of emergency workers led to the deaths of 31 people, including 28 firemen. The firemen received large external doses from deposited radionuclides,

between 3 and 16 Sv, and contamination on their skin led to severe erythema, mostly due to beta emitters. In terms of dose to people in the vicinity and beyond the most significant radionuclides were iodine-131, caesium-134 and caesium-137 almost all the dose was caused by external irradiation from radionuclides on the ground by inhalation of iodine-131 giving rise to thyroid doses, and by internal irradiation from radionuclides in foodstuffs.

Further studies of populations in the vicinity of Chernobyl and elsewhere, looking for possible health effects from the accident. The only significant effect that has so far been shown to be caused by radiation is in children in regions of Belarus and Ukraine who have an increased incidence of thyroid cancer due to intakes of Iodine-131, particularly through drinking milk contaminated with iodine. Iodine-131 is a short lived radionuclide known to concentrate in the thyroid and using monitoring and other data it has been possible to estimate risk factor for this health effect in children. In 2000, UNSCEAR published a review of the effects of Chernobyl accident. The other serious health effects seen in local populations appear to be the result of the stress and anxiety caused by the accident, including the fear of radiation itself. Although these effects are different in kind to the thyroid disorders mentioned above.

5.1. Depletion of Uranium

Uranium occurs naturally in the environment. It is widely dispersed in the earth crust and in fresh water and sea water. As a result we are all exposed to uranium isotopes and their decay products and there are wide variations in doses received depending on local circumstances. Depletion of uranium is a by-product of the uranium fuel cycle where natural uranium is enriched to provide suitable fuel for nuclear power. It is called depleted because it has had some of its Uranium-235 isotope removed. A large fraction of decay products of the uranium isotopes is removed during the fuel enrichment process.

Doses to people exposed some time afterwards to resuspended dust in the same local environment are likely to be a thousand times less, typically a few tens of μSv . Contact doses when handling bare depletion of uranium metal are approximately 2.5 mSv/h, primarily from beta radiation which is not penetrating and so affects only the skin.

6. Impacts of Radionuclides on Human Health

(i) Radiation Effects:

Radiation doses of different sizes, delivered at different rates to different parts of the body, can cause different types of health effect at different times. A very high dose to the whole body can cause death within weeks. For example an absorbed dose of 5 grey or more received instantaneously would probably be lethal unless treatment given, because of damage to the bone marrow and the gastrointestinal tract. An instantaneous absorbed dose of 5 grey to the skin would probably cause erythema (painful reddening of the skin) within a week or so whereas a

similar dose to the reproductive organs might cause sterility. This type of effect is called deterministic effect. This occurs only if the dose or dose rate is greater than some threshold value, and the effect occurs earlier and is more severe as the dose and dose rate increased.

Deterministic effects in an individual can be identified clinically to be the result of radiation exposure. One type of deterministic effects occurs a longer time after exposure. Such effects are not usually fatal, but can be disabling or distressing because the function of some parts of the body may be impaired or other non-malignant changes may arise. The best-known examples are cataracts (optically in the lens of the eye) and skin damage (thinning and ulceration) high absorbed doses of several grey are normally required to induce these conditions.

(ii) Induction of Cancers:

The most important of these stochastic effects is cancer, which is always serious and often fatal. Although the exact cause of most cancers remains unknown or poorly understood, exposure to agents such as tobacco smoke, asbestos and ultraviolet radiation as well as ionizing radiation is known to play a role in inducing certain types of cancer. The development of cancer is complex, multistage process that usually takes many years. Radiation appears to act principally at the initiation stage by introducing certain mutations in the DNA of normal cells in tissues. These mutations allow a cell to enter a pathway of abnormal growth that can sometimes lead to the development of a malignancy.

As we cannot calculate the risk of cancer from radiation, in practice we have to use epidemiology - the statistical study of incidence of specific disorders in specific population groups. Suppose that we know the number of people in an irradiated group and the doses they have received. Then by observing the occurrence of cancer in the group and comparing with the doses and the number of cancers expected in an otherwise similar but unirradiated group, we can estimate the raised risk of cancer per unit dose. This is commonly called risk factor. It is most important to include data for large groups of people in these calculations so as to minimize the statistical uncertainties in the estimates and take account of factors such as age and gender that affect the spontaneous development of cancer.

Not all cancers are fatal. Average mortality from radiation induced thyroid cancer is about 10 % (although it is much lower - less than 1% for the cases caused in children and teenagers by the Chernobyl accident) from breast cancer about 50% and from skin cancer about 1%. Overall the total risk of inducing cancer by uniformly irradiating the whole body is about half as great again as the risk of inducing a fatal cancer. In radiological protection the risk of fatal cancer is of more concern because of its extreme significance. The use of fatal cancer risks also makes it easier to compare them with the other fatal risks encountered in life. In contrast comparisons of non-fatal risks are fraught with difficulty.

(iii) Hereditary Disease:

Apart from cancer the other main late effect of radiation is hereditary diseases with cancer the probability of hereditary disease but not its severity depends on dose.

Genetic damage arises from irradiation of the testes and ovaries which produce sperm cells in males and egg cells in females. Ionizing radiation can induce mutations in these cells or in the germ cells that form them, mutations which may give rise to harmful effects in future generations. Mutations occur as a result of structural changes to DNA in single germ cells, which subsequently carry the hereditary information in the DNA through future generations.

The hereditary diseases that may be caused vary in severity ranging from early death and serious mental defects to relatively trivial skeletal abnormalities and minor metabolic disorders. Although mutations appear to arise in human beings without any apparent cause, natural radiation and other agents in the environment may also cause them and contribute to the prevailing occurrence of hereditary disease. There has however been no conclusive evidence in human offspring for hereditary defects attributable to exposure from natural or artificial radiation. Large experimental studies have been made of the hereditary damage that ionizing radiation induces animals mainly mice. These have covered with a range of doses and dose rates and clearly demonstrate that ionizing radiation does cause mutations. The results also show how often hereditary defects are induced by known doses. When considered with the findings for the atomic bomb survivors, this information allows estimates to be made of hereditary risk for human beings.

Mutations leading to diseases that are strictly heritable, such as hemophilia and Down's syndrome make up about half of the total: the remainder comes from a group of so called multi factorial diseases, such as diabetes and asthma. Irradiation of the testes and ovaries only carries a risk of hereditary effects if it occurs before or during the reproductive period of life. For a population exposed to radiation in one generation only the risks to the first post irradiation generation were estimated to be 0.3-0.5 % per Gy. This is between one-third and one half the ICRP estimate for all generations quoted above. The risks to generations other than the first are much lower than this. Put another way this new estimate of risk per gray is of the order of 0.4-0.6 % of the baseline frequency of these disorders in the human population.

(iv) Irradiation Effect in Pregnancy:

The risks to children irradiated while in the womb deserve special mention. If an embryo or fetus is exposed to radiation at the time when organs are forming, developmental defects such as a reduced diameter of the head or mental retardation may be caused. Exposure of the fetus to 5 mSv during this stage of pregnancy would lead to loss in IQ of 0.15 point, which would be undetectable high doses to the embryo and fetus can cause death or gross malformation. The threshold for these effects is between 0.1Sv and 1Sv or more depending on the time after conception. Genetic risks to fetuses are judged to be the same as those for awfully reproductive population after birth, namely $2.4 \times 10^{-2} \text{ Sv}^{-1}$ or 1 in 40 per Sv. Irradiation before birth can also lead to an increased risk of malignancy in childhood. For all of these reasons it is best for pregnant women to avoid diagnostic X-rays of the abdomen unless a delay until the end of pregnancy would be desirable.

Table 3. Harmful Radiation Effects

Circumstances of Exposure Information	Health Consequences	Sources of Information
High dose and dose rate To much of the body To area of skin To tests and ovaries	Early Effects Death Erythema Sterility	Human data from various sources
Any dose or dose rate Risk depends on dose appear years later	Late Effects Various Cancers	Risk factors for human beings estimated by extrapolating human data for high doses and dose rates
Any dose or dose rate risk depends on dose appear in offspring	Hereditary defects	Risk factors for human beings inferred from animal data and the absence of human evidence
High dose at any rate various times to appear	Functional damage	Human data from various sources
Dose in the womb appears in the child	Mental retardation	Limited human data

7. Controlling Measures

The control of ionizing radiation is heavily regulated. Expert advice should be sought prior to introducing sources of radiation onto the premises. The general provisos for the control are that:

- Aqueous radioactive wastes can be treated mainly by the methods of Ion exchange, Chemical precipitation, Evaporation or Ultra filtration / Reverse Osmosis.
- All radioactive exposures maintaining shall be as low as reasonably practice
- The dose received shall not exceed specified limits. As with most hygiene standards these limits vary slightly between nations: local values should be consulted.
- Exposure is minimized by choice of source by duration of exposure by distance from source and by shielding.
- Conduct a risk assessment to any employee and other persons to identify measures needed to restrict exposure to ionizing radiation and to assess magnitude of risk including identifiable accidents.
- Provide barriers for identification and display of appropriate warning notices, e.g. Trefoil symbol.
- Use remote handling techniques where necessary.
- Appoint a radiation protection adviser: all staff involved with radioactive work should be adequately trained and instructed. Provide mandatory medical surveillance for classified workers.
- Removing contaminated soil from small and large areas.

8. Conclusion

Radioactive materials are extensively used in industrial and research activities into medical, agriculture and environmental applications and in various other areas during the production and use of these materials,

radioactive waste will inevitably arise. This must be managed with particular care owing to its inherent radiological, biological, chemical and physical hazards. To protect living organisms from the harmful effects of radiation human must be cautious about their activities. By practicing the above mentioned controlling measures there is a chance of reducing the effects of radiation.

References

- [1] Phillip Carson, *Hazardous chemical Handbook*, second edition. (2002). Butterworth-Heinemann An imprint of Elsevier Science, Woburn, MA 01801-2041.
- [2] A.D. Wrixon, *Radiation, People and the Environment*, (2004), International Atomic Energy Agency (IAEA).
- [3] *Radiation and The Environment: Assessing effects in plants and animals an over view of recent report* issued by the United Nations Scientific Committee on the effects of Atomic Radiation by Gordon Linsley-IAEA Bulletin,39/1/1997 pg. no.17-18.
- [4] www.iaea.org-International Atomic Energy Agency (IAEA).
- [5] Tan Ee lyn, *The Thomson Results Trust Principles*, Taiwan Atomic Energy Council, Word Nuclear Association, US Environmental Protection Agency, Japan's Ministry of health, Hong Kong's Center for food safety.
- [6] The Effects on Health of Chronic Contamination with a Low Dose of Radionuclides. Juillet-2011, IRSN-Institute of Radio Protection ETDC SURETE Nucleaire.
- [7] *United Nations Scientific Committee on the effects of Atomic Radiation (UNSCEAR) Sources and effects of ionizing radiation* UNSCEAR, 1996 Report to the general assembly, with scientific Annex, united nations sales publication E.96. IX.3. (1996).
- [8] Valdovinos. V, Monroy-Guzman. F and Bustos. E, Treatment Methods for Radioactive Wastes and its Electrochemical Applications, pg. no. 402.



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