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Radiation Biodosimetry: Current Use and Future Needs

KEYWORDS

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Introduction
In today"s lifestyle, radiations find a lot of potential appli cations as well as pit- falls and are used in a variety of areas such as:

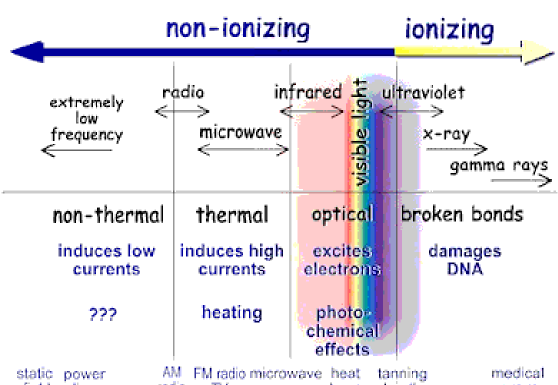
Communication

Medicine

Agriculture and food industry

Energy Production

However, all ionizing radiations pose some sort of, if minimally significant health hazard to the quality of human life. It is impossible to terminate the usage and application of radiations, but it is possible to restrict or modify their usage taking into consideration the risk involved both to the personnel working with radiations as well as to the general population. Numerous historical events have carved our under-

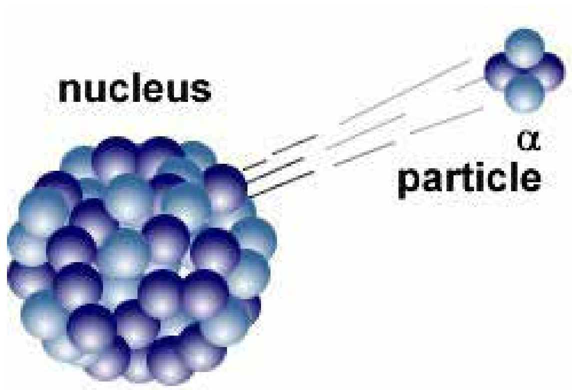


standing of the consequences of radiation disasters. In recent decades accidents at nuclear power plants have led to discharge of radioactive substances into the envi- ronment. Children are more vulnerable to risk induced by acute or chronic radiation exposure. Radiation in-

The detrimental effects of high dosages of radiation on the human body have been effectively documented in ecodisasters such as the Chernobyl Power Plant mishap in 1986. Of the total of 499 people were admitted for observation, 237 of these were ini- tially diagnosed as suffering from acute radiation syn- drome. The severity and rapidity of onset of their symp- toms depended on their dose. The initial early signs and symptoms of radiation sickness from high doses included diarrhoea, vomiting, fever and erythema. Over

200 patients were placed in regional hospitals and spe- cialized centre in the first 24 hours. Patients were allo- cated to four categories of radiation sickness severity according to their symptoms, signs and dose estimates. The differential white blood cell count showed reduced circulating lymphocytes (lymphocytopenia) which was the initial indicator of the severity of the exposure and became evident in the first 24 to 36 hours for those most severely irradiated.[1] Even though there were only 50 "direct deaths" , about 4000 thousand deaths owing to cancer are expected in the 6,00,000 people who were expose to a hazardously high level of radia- t i o n . [2]

In an accident, radionuclides contaminate bod- ies of water not only directly from deposition from the air and discharge as effluent, but also indirectly by washout from the catchment basin. Radionuclides con- taminating large bodies of water are quickly redistrib- uted and tend to accumulate in bottom sediments, ben- thos, aquatic plants and fish. The main pathways of potential human exposure may be directly through con- tamination of drinking-water, or indirectly from the use of water for irrigation and the consumption of contami- nated fish. As contaminating radionuclides tend to dis- appear from water quickly, it is only in the initial fall- out phase and in the very late phase, that the contami- nation washed out from the catchment area reaches drinking-water supplies. This is a likely cause of human



exposure. Fallout consists of radioactive material that reaches the upper atmospheric layers at the time of the accident and then later falls back to the earth's surface. [3]

In April 2010 in New Delhi (India) there was exposure to high intensity radiation from Cobalt-60 which was disposed off as scrap. The incident came to light after a worker fell unconscious and his hands turned black after coming in contact with the object. [4]

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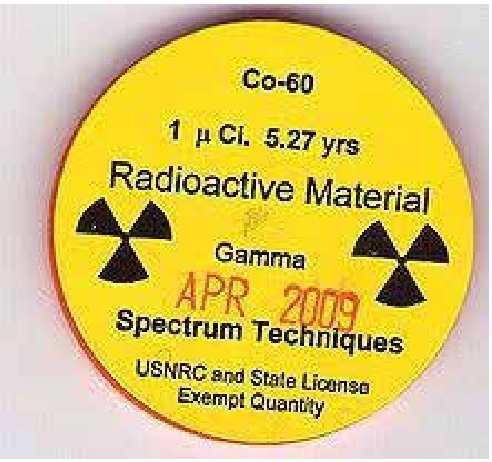

A whole body radiation exposure of about 1.5 G, within a few minutes to hours after exposure, results in symptoms characteristic of gastro- intestinal disturbances. The patients often suf- fer from anorexic, nau-sea, vomiting, diarrho-ea, weakness and fatigue. Whole body exposures of 2 to 7Gy affect haemopoietic stem cells of bone marrow and spleen. Gastro-intestinal syndrome results from exposures in the range of 7 to 15 Gy and causes extensive damage to the gastro-intestinal system. Whole body exposure in excess of 50 Gy causes cardiovascular and central nervous system syndrome. Victims show intermittent stupor in-coordination, disorientation and convulsion suggestive of extensive damage to the nervous system.

Risk Assessment

Risk is defined as "some impact on health and safety" or "probability of harmful effects on a human", and is a technical measure of health impacts. No human activity is without risk. The severity of the risk therein has to be assessed solely by the participant of the par- ticular activity. Risk vs. Benefit is another parameter that has to be considered. Risk assessment is a technical measure of health effects. It tells us specifically what, when and in what proportion an unfavourable effect is most likely possible.

Radiation, is a term which is quite well known and suffi- ciently investigated by techni- cians and clinicians but is re- garded a controversial topic by the public at large.

"Health risks of radiation ex- posure can only be estimated with a reasonable degree of scientific certainty at radiation levels that are orders of magni- tude greater than levels es-tab-lished by regulators for protection of the public." [5]

Parameters

Risk assessment should be carried out keeping in mind the current levels of radiation to which the population native to the area are being exposed to and the access of population not native to that area. Also before beginning any project which is expected to bring about a change in the current level of radiations experi- enced, it would be prudent to estimate the radiation lev- els expected to be reached after the completion of the project. The safety measures in place should be checked, in order to get an estimation of, or to limit radiation leaks to the environment. The possibility of an accident which will have direct effects on the environment has to be considered, along with standards of physical protection, in the eventuality of such a mishap. Previous records of surveys, if any, as regarding personal dosimetry would provide relevant information. Some assessments look at impacts after an event, while some others look ahead to predict what the effects will be.

Phases of Risk Assessment

There are four phases in conducting risk as- sessments: identifying hazards, estimating exposure, assessing potential health dangers, and characterizing or describing the risk.[6]

Identifying Hazards

When assessments are done after an event has occurred, radioactive biomarkers can be isolated from soil, air, water, flora & fauna. Comparing this to the

results obtained before gives a significant idea of the increase in radioactive levels.

Estimating Exposure

Risk assessors calculate quantities of a given radionuclide that could reach a person's lungs, digestive system, or skin. This will help know:

The amount of exposure through food, water, air The access of the general population to that area The risk posed to future habitation in that area

Assessing Potential Health Dangers

While calculating risk assessment, it is essen- tial to take in account potential health dangers caused by future exposures.

Characterizing (Describing) Risk

Taking under consideration the values ob- tained from the above methods, the following personnel work as follows:

Risk Assessor: Calculates the total risk, from ex- trapolating the above data

Risk Manager: Contains the risk and takes preven- tive measures

Modalities

Electron Paramagnetic Resonance is a modern modality which makes the use of minimal amount of an enamel sample and assesses the radiations it has been exposed to. The spectrographic analysis of the sample gives an idea about the qualitative and quantitative as- pects of radiation by detecting species of unpaired elec- trons

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The technique most recently in use as concerns radiation biodosimetry is the use of Electron Paramag- netic Resonance. Radiation induced Electron Paramag- netic Resonance signals were first reported by Gordy et al.[7]

The applications of EPR include:

Dose reconstruction Radiation therapy Food irradiation

Quality assurance programmes Archaeological dating Epidemiological accidents Biodosimetry applications Accidental over exposures

Radiopharmaceutical dose assessment

Retrospective Epidemiological Studies

exposure:

Hiroshima, Japan (1945) Mayak, Russia (1948-1961)

Techa Riverside Population, Russia (1948 -1958) Totskoye Nuclear Test, Russia (1954)

Chernobyl, Ukraine (1986)

However some anomalies may arise due to improper separation of material, improper collection of samples and inadequate methods of spectrum process- ing.[8]

Materials that have been studied include bone, tooth, enamel, alanine & quartz. The technique basically deals with detection of chemical species con- taining unpaired electrons formed in enamel. Electrons trapped in radiation damaged sites are detected using this method. Moreover a very small amount of sample is required, which would, in no way, affect the func- tional integrity of the tooth. Electrons, in a magnetic field have two different states of energy. They can jump between these states only when resonance oc- curs. The hardware required includes an electromagnet for power supply, a microwave generator and an am- plifier and recorder.

The bands used are:

L-band: for large samples

X-band: most frequently used

Q-band: for small samples

As enamel has the highest degree of minerali- zation, shows a linear dose dependence relationship, and is sensitive to x-rays, gamma rays and beta rays, this makes it ideal for study. However, the enamel has to be separated from dentin using physical (with a drill), semi physical (etching and use of phosphoric acid), or chemical methods, (use of NaOH or KOH). This method has been used successfully in the following places with the stated periods being those of over-

EPR dosimetry procedures over the last dec-ade have served as a routine dosimetric modality. In this method appropriate result with tooth enamel can be attributed to radiation induced radical which reside in hydroxyapatite matrix. The fingernails are also used for precise determination of radiation dose exposure. The added advantage of using finger nails, bones & teeth biodosimetry is that the possibility of heteroge- neous exposure to different parts of the body can be assessed. The main component of nails is hard keratin, consisting of a crystalline fiber phase and of an amor- phous protein matrix phase. The fiber phase consists of a-helical peptide chain coiled to stable micro- fi- brils.

However, the feasibility of these approaches to large scale incidents needs to be evaluated. The inci- dents that expose humans to ionizing radiation are stark reminders of potential hazards that should not be ig- nored. The public health policies need to be improvised to minimize unnecessary exposure to the patients. This is possible by enforcing dose limits for exposure of workers/population and application of standards for equipment and operatories where radiation sources are used. In view of increasing number of operatories, ra- diation risk assessment of induced acute and chronic effects and its mitigation deserves to be an integral part of the healthcare system.

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