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REVIEW ON RADIO ACTIVE ISOTOPES AND ITS APPLICATIONS

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ABSTRACT

The field of nuclear medicine uses radiation to provide diagnostic information about the functioning of humans or information on how to treat them. Tens of millions of nuclear medicine procedures are performed each year and the demand for radioisotopes for medical use is increasing rapidly. Isotopes which have atoms with identical atomic numbers but different mass numbers. Isotopes are available in naturally and stable. Some of A few naturally occurring isotopes and all of the man-made isotopes are unstable. Unstable isotopes can become stable by releasing different types of particles. This process is called radioactive decay and the elements which undergo this process are called radioisotopes/radionuclides. Stable and radioactive isotopes (radioisotopes) are utilized in a variety of medical and industrial applications ranging from diagnostic and therapeutic products to screening devices used to detect explosives and drugs. Isotopes are used to irradiate food and medical supplies to reduce bacterial levels and minimize spoilage. The present review describes that production of radio isotopes, applications of isotopes and therapeutic achievements of radioactive isotopes.

KEYWORDS: Radiation, Isotopes, Radioactive decay, Atomic number, Mass number.

INTRODUCTION

Radioactivity is the spontaneous decomposition or disintegration of a nucleus forming a different nucleus and producing one or more additional particles. Radioactive decay is a process by which the nuclei of a nuclide emit α, β or γ rays. In the radioactive process, the nuclide undergoes a transmutation, converting to another nuclide. Radionuclide imaging (or functional imaging) is a branch of medicine which provides the only means of assessing physiologic changes that is a direct result of biochemical alterations. In most cases, the information is used by physicians to make a quick, accurate diagnosis of the patient's illness.[1] This imaging is based on the radiotracer method which assumes that radioactive atoms or molecules in an organism behave in a manner identical to that of their stable counterparts because they are chemically indistinguishable.

Definition of Isotopes and Radioactive isotopes

Matter is composed of atoms whose nuclei contain protons and neutrons. The number of protons in the nuclei determines whether the atom is hydrogen, carbon, uranium, oxygen, or one of the other 115 currently known elements. For example, most carbon atoms will have 6 protons and 6 neutrons. Atoms of the same element, however, may have different numbers of neutrons in their nuclei. The various forms of an element that differ only in the number of neutrons are referred to as isotopes; one element may have many different isotopes.[2] Some carbon atoms have five, seven, or eight neutrons. Since an isotope is identified by the element name and its atomic weight (i.e., the sum of the protons and neutrons in each atom), carbon atoms with six neutrons in their nuclei (the dominant form) have an atomic weight of 6+6=12 and are referred to as carbon-12 Carbon atoms with five, seven, or eight neutrons in their nuclei are referred to as carbon-11, carbon-13, and carbon-14, respectively. Isotopes of the same element generally have virtually identical chemical characteristics but may differ in other ways. For example carbon-12 is stable whereas carbon-14 is unstable, or radioactive. Stable isotopes maintain their nuclear structure without changing over time. Radioactive isotopes, referred to as radioisotopes or radionuclides, have unstable nuclei which spontaneously disintegrate and release energy in the process to form other nuclear particles that can be detected by a radioactivity-measuring instrument.

Stable isotopes are generally "produced" by enriching or concentrating the isotope of interest from sources in which the isotope is naturally found admixed with others. The separation process exploits the different physical properties of the individual isotopes. For example, many of the heavier stable isotopes have been produced by electromagnetic separators known as calutrons. More efficient methods utilizing gas centrifuges, thermal diffusion and cryogenic distillation techniques, however, are said to be replacing calutrons.[3]

History of Radioactive Isotopes

Radioactivity was not invented by man. It was discovered just over a century ago, in 1896, by the French physicist Henri Becquerel. He was attempting to find out whether the rays emitted by fluorescent uranium salts were the same as the X-rays discovered in 1895 by the German physicist Wilhelm Roentgen. He thought that the uranium salts, after being excited by light, emitted these X-rays. Imagine his surprise when, in Paris in March 1896, he discovered that photographic film had been exposed without Radioactivity was not invented by man. It is a natural phenomenon that was discovered at the end of the 19th century. Exposure to sunlight! He concluded that uranium emitted invisible radiation, different from X-rays, spontaneously and inexhaustibly. The phenomenon he discovered was named radio activity Following Henri Becquerel's work, in 1898 Pierre and Marie Curie isolated polonium and radium, unknown radioactive elements present in uranium ore.[4]

Production of Radioactive Isotopes

Radioisotopes are produced artificially from the bombardment of a stable isotope either with neutrons in a nuclear reactor or with protons or other charged particles in an accelerator. An accelerator is a device that accelerates electrically charged particles to extremely high speeds for the purpose of inducing high energy reactions or producing high energy radiation.

Radioactive products which are used in medicine are referred to as radiopharmaceuticals. Radiopharmaceuticals differ from other medically employed drugs since they generally elicit no pharmacological response (owing to the minute quantities administered) and they contain radionuclide. They are prepared by tagging the chosen carrier component with an appropriate radioactive isotope.[5] The carrier component of the radiopharmaceutical is a biologically active molecule used to localize the drug in a specific organ or group of organs to provide diagnostic information about those tissues such as pyrophosphate and methylene diphosphonate (MDP) compounds in skeleton bone tissues.

Applications of Radioactive Isotopes

Using of these isotopes in various sectors like industries, agriculture, healthcare and research centres has got a great importance at present. In health care sector, these isotopes are used in nuclear medicine as diagnostic and therapeutic modalities. radionuclide imaging (or functional imaging) is a branch of medicine which provides the only means of assessing physiologic changes that is a direct result of biochemical alterations and is based on the radiotracer method.

Table 1: Difference between stable isotopes and radioactive isotopes.

Stable Isotopes	Radioactive Isotopes
Most abundantly found in nature	Less abundance of natural radioisotopes
No emission of radiation	Spontaneous emission of radiations(α,β,γ)
Atomic number and mass are constant	Constantly changing
Detection by chemical/spectroscopic methods	Detection by external detectors like gas chambers/ scintillation
Not hazardous(except toxic chemicals)	Deleterious effects on biological tissues
No special handling precautions (unless explosives/ strong acids/carcinogens)	Special precautions while handling.
No special applications	Special applications in research(mutagenesis)/diagnosis (RIA)/therapy(Rx of cancer)

Table 2: List of Therapeutically used Radioisotopes.

S. No	Radioisotope	Half life	Use
1	Cabon-11	20.3mins	Brain scans
2	Chromium-51	27.8 days	Blood volume determination
3	Cobalt-57	270 days	Measuring vitamin B12 uptake
4	Cobalt-60	5.26 years	Radiation cancer therapy
5	Gadolinium-153	242 days	Determining bone density
6	Gallium-67	78.1 days	Scan for lung tumors
7	Iodine-131	8.07 days	Thyroid therapy
8	Iridium-192	74 days	Breast cancer therapy

9	Phosphorus-32 and Phosphorus-33	14.3 days	Detection of skin cancer and eye tumors
10	Technetium-99m	6.0hrs	Imaging of brain, liver, none marrow, kidney, lung or heart
11	Thallium-201	72 hrs	Detecting heart problems and tread mill stress test
12	Tritium	12.3 yrs	Determining total body warer
13	Xenon-133	5.27d	Lung imaging
14	Plutonium-238	86 yrs	Power for pacemakers
15	Slenium-75	120 days	Pancreas scans
16	Sodium-24	15.0 hrs	Locating obstructions in blood flow
17	Iron-59	45 days	Detection of anemia

Applications of Radioisotopes in Agriculture

Plant nutrition studies: Fertilizers are very expensive and their efficient use is of great importance to reduce the production cost of agricultural crops. It is essential that a maximum amount of fertilizer used during cultivation finds its way into the plant and that the minimum is lost. Radioisotopes are very useful in estimating the amount of phosphorus and nitrogen available in the soil. This estimation helps in determining the amount of phosphate and nitrogen fertilizers that should be applied to soil. Fertilizers labelled with radioactive isotopes such as phosphorus-32 and nitrogen-15 have been used to study the uptake, retention and utilization of fertilizers.[6] Excessive use of fertilizers effects biodiversity and damages the environment. These isotopes provide a means to determine about amount of fertilizer taken and lost to the environment by the plant. Study of soil characteristics is extremely valuable in devising effective methods of farming. Radioactive isotopes can be used as "tags" to monitor uptake and use of essential nutrients by plants from soil. This technique allows scientists to measure the exact nutrient and water requirements of crop in particular conditions. A major factor in successful crop production is the presence of an adequate water supply. Nuclear moisture density gauges can monitor and determine the moisture content of soil so indicates the exact irrigation needs of a particular area. Nuclear science and technology have greatly facilitated such investigations and are now being widely used in soil plant nutrition research to make the most efficient use of limited water sources. [6] Ionizing radiation is also used to sterilize the soil and there is a good deal of current interest in the use of radiation for the eradication of microorganisms in the soil which causes diseases and are harmful to plant life.

Insect pest management: Insect pests are responsible for significant reduction in production of agricultural crops throughout the world. Insect pests are serious threat to agricultural Productivity. They not only reduce crop yields but also transmit disease to cultivated crops. Radiolabel pesticides were used to monitor the persistence of their residues in Food items, soil, ground water and environment. These studies have helped to trace and minimize the side effects of pesticides and insecticides. There are concerns that continuous uses of pesticides have negative impacts on the environment and it also results into development of resistance against pesticides in many insect species. Moreover, pesticides not only kill target species but also many other beneficial pest species responsible for maintaining natural ecological balance in the crop fields. They have placed considerable emphasis on the Sterile Insect Technique (SIT). This technique relies on application of ionizing radiation as a means to effectively sterilize male insects without affecting their ability to function in the field and successfully mate with wild female insects. This technique involves release of large numbers of sterile male insects of the target species in the field crop. Sterile male insects compete with the regular male population during sexual reproduction and the eggs produced from their mating are infertile so they produce no offspring. It is highly specific form of birth control which reduces and eliminates the insect population after two or three generations.[7]

Crop improvement: Plant breeding requires genetic variation of useful traits for crop improvement. Different types of radiation can be used to induce mutations to develop desired mutants line that are resistant to disease, are of higher quality, allow earlier ripening, and produce a higher yield. An initial attempt to induce mutations in plants was demonstrated by American Scientist L.J. Stadler in 1930 using X-rays. Later on, gamma and neutron radiation were employed as ionizing radiations. This technique of utilizing radiation energy for inducing mutation in plants has been widely used to obtain desired or improved characters in number of plant varieties. It offers the possibility of inducing desired characters that either cannot be found in nature or have been lost during evolution.[8] A proper selection of mutant varieties can lead to improved quality and productivity. During last two decades, radiation-induced mutations have increasingly contributed to the improvement of crop plant varieties and it has become an established part of plant breeding methods. Radiation induced mutation experiments are showing promising results for improvement of cultivated crop varieties in many countries.[9]

Food processing and preservation

Demand for instant food which is wholesome and which has a long shelf life is growing in both the developed and the developing countries. 25-30% of the world's food produce are lost due to spoilage by microbes and pest and these losses are more in developing countries. This loss of food can be avoided by employing efficient food preservation methods. Radiation can be used to destroy microbes in food and control insect and parasite infestation in harvested food to prevent various kinds of wastage and spoilage. Extension of shelf life of certain foods of a few days by irradiation is enough to save them from spoiling. Irradiation of food has potential to produce safe foods with long shelf life. Certain seeds and canned food can be stored for longer periods by gently exposing them to radiations. Food irradiation is energy-conserving when compared with conventional methods of preserving food to obtain a similar shelf-life. It can alleviate the world's food shortage by reducing post-harvest losses. Food irradiation can replace or drastically reduce the use of food additives and fumigants which are hazardous for consumers as well as workers in food processing industries.[10,11] Irradiation does not heat the food material so food keeps its freshness in its physical state.

Medical uses of Radioactive Isotopes

Approximately 10% of medical procedures use radiation to treat a variety of diseases, including many types of cancers, heart disease, gastrointestinal, endocrine, neurological disorders and other abnormalities within the body. Approximately 68 million CT scans are performed in the U.S according to the National Council on Radiation (NCRP).[12]

X-Rays: X-ray images are produced by placing a patient between an x-ray tube and a photographic plate. An image on the film of the area exposed can then be reviewed. Common x-rays are made of teeth, bones, and breasts (mammograms).

Magnetic Resonance Imaging: MRI is an imaging technique used to visualize internal structures of the body in detail. MRI can create more detailed images of the human body than is possible with X-rays. This procedure uses a magnetic field and pulses or radio waves to make pictures of organs and structures inside the body. The water in our bodies is made up of millions of atoms that are magnetically charged.[13]

Medical Imaging / Radiotracers

Positron Emission Tomography: This nuclear medical imaging technique involves the injection into the body of an isotope that decays by positron emission that is the beta plus (B+) particle. When this positron encounters an electron, a beta minus particle, they annihilate each other and produce two photons. The energy and path of these photons leaving the body can then be used to give an accurate picture of the area where the isotope was absorbed.

Smoke Detectors

Most smoke detectors which operate alarms contain an artificially produced radioisotope: americium-241.[14]

1. Americium-241 is made in nuclear reactors, and is a decay product of plutonium-241.
2. Smoke detectors/alarms are important safety devices, because of their obvious potential to save lives and property.
3. There are two types of smoke detector commonly available in many countries. One type uses the radiation from a small amount of radioactive material to detect the presence of smoke or heat sources. These 'ionization chamber' smoke detectors are the most popular, because they are inexpensive and are sensitive to a wider range of fire conditions than the other type. They contain some americium.
4. The other type of detector does not contain radioactive material; it uses a photoelectric sensor to detect the change in light level caused by smoke. This type is more expensive to purchase and install, and is less effective in some circumstances.
5. The element americium (atomic number 95) was discovered in 1945 during the Manhattan Project in USA. The first sample of americium was produced by bombarding plutonium with neutrons in a nuclear reactor at the University of Chicago.
6. Americium-241, with a half-life of 432 years, was the first americium isotope to be isolated, and is the one used today in most domestic smoke detectors.
7. Am-241 decays by emitting alpha particles and gamma radiation to become neptunium-237.
8. Americium dioxide, AmO2, was first offered for sale by the US Atomic Energy Commission in 1962 and the price of US$1500 per gram has remained virtually unchanged since. One gram of americium oxide provides enough active material for more than three million household smoke detectors.
9. The vital ingredient of household smoke detectors is a very small quantity of Am-241 as americium dioxide (AmO2).
10. The alpha particles emitted by the Am-241 collide with the oxygen and nitrogen in air in the detector's ionization chamber to produce charged particles (ions).
11. A low-level electric voltage applied across the chamber is used to collect these ions, causing a steady small electric current to flow between two electrodes. When smoke enters the space between the electrodes, the smoke particles attach to the charged ions, neutralizing them. This causes the number of ions present – and therefore the electric current – to fall, which sets off an alarm.
12. The radiation dose to the occupants of a house from a domestic smoke detector is essentially zero, and in any case very much less than that from natural background radiation. The alpha particles are absorbed within the detector, while most of the gamma rays escape harmlessly.
13. The small amount of radioactive material that is used in these detectors is not a health hazard and individual units can be disposed of in normal household waste.
14. Even swallowing the radioactive material from a smoke detector would not lead to significant internal absorption of Am-241. Americium dioxide is

insoluble, so will pass through the digestive tract without delivering a significant radiation dose.

15. Americium-241 is however a potentially dangerous isotope if it is taken into the body in soluble form. It decays by both alpha activity and gamma emissions and it would concentrate in the skeleton.
16. The annual dose at 1m delivered by an average household smoke detector is ~100 times lower than dose from natural background radiation.[15,16]

Tritium in Exit Signs: Exit signs are mounted in almost every building we enter; schools, grocery stores, movie theatres and shopping malls. Many exit signs contain tritium, the radioactive form of hydrogen.[17]

1. They light the sign without batteries or electricity.
2. Using tritium in exit signs allows the sign to remain lit if the power goes out as it might if there is a storm or a fire.
3. Tritium is most dangerous when it is inhaled or swallowed.
4. When tritium is mixed with certain chemicals, it creates a continuous, self-powered light source. Tritium exit signs are used when dim light is needed, but using batteries or electricity is not possible.
5. Tritium can be naturally produced or man-made. Exit signs use man-made tritium.
6. Because a damaged tritium exit sign will have relatively high levels of tritium in it, you should leave the area immediately and call for help.
7. Damage to tritium exit signs is most likely to occur when a sign is dropped during installation or smashed in the demolition of a building.
8. Unwanted tritium exit signs may not be put into ordinary trash.
9. Tritium exit signs that are illegally put in ordinary landfills can break and contaminate the groundwater.
10. Tritium exit signs require special disposal. The person who was put in charge of the tritium exit signs when they were purchased is responsible for disposing of them. That person must follow special rules for their disposal.
11. Tritium has a half-life of 12.32 years meaning that it loses half its brightness in that period.
12. It emits beta particles, which are most harmful when inhaled or swallowed. Internal contamination occurs when people swallow or breathe in radioactive materials, or when radioactive materials enter the body through an open wound or are absorbed through the skin. Tritium must be ingested in large amounts to pose a significant health risk.

Applications for radio tracers in industry

Industry uses many complex reactors with opaque walls. Radioactive tracers can be detected through these walls, so they can be used to study the behavior of fluids within these reactors. Many industries use this technique: chemistry, oil and petrochemicals, the manufacture of cement, fertilizer, paper pulp, chlorine, soda, explosives, metallurgy, energy, etc. The operation involves tagging a short burst of matter at the input to the equipment and studying and observing the tracer concentration signal curve over time at different places.[18,19]

CONCLUSION

Nuclear medicine was now days most commonly used in treatment of various diseases like cancer, tumors and some heart problems. Commonly used nuclear medicine like radioactive isotopes and radiotracers in medical imaging. These are also used in other fields like agriculture and industrial technologies. Nuclear medicine and molecular imaging, which provides the only means of assessing physiologic changes that is a direct result of biochemical alterations at cellular and molecular levels, and in combination with traditional anatomic imaging such as computed tomography scan and magnetic resonance imaging (MRI) scan, provide precise localization of functional abnormalities. Many elements which found on earth exists in different atomic configurations used in medicine are referred to as radiopharmaceuticals which are useful to get diagnostic and therapeutic information about those tissues.

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