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Biological Effect of Gamma Radiations

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Abstract

Radiation is the emission or transmission of energy as waves or particles through space or through a material medium which is able to penetrate various materials and is often categorized as either ionizing or non-ionizing depending on the energy of the radiated particles. Radiation processing can be defined as exposure of materials with high energy radiation to change their physical, chemical, or biological characteristics, to increase their usefulness, and safety purpose, or to reduce their harmful impact on the environment. Ionizing radiation is produced by radioactive decay, nuclear fission, and fusion, by extremely hot objects, and by particle accelerators. The radiation coming from the sun is due to the nuclear fusion; therefore, we are living in a natural radioactive world. Radioactive substances are common sources of ionized radiation that emit α, β, or γ radiation, consisting of helium nuclei, electrons or positrons, and photons, respectively. Alpha rays are the weakest form of radiation and can be stopped by paper. Beta rays are able to pass through paper but not through aluminum. Gamma rays are the strongest radiation. They are able to pass through paper and aluminum, but not through a thick block of lead or concrete. Alpha and beta radiation are the high energy subatomic particles where gamma radiation is a form of high energy electromagnetic waves. This review presents the fundamental introduction of radiation, the three types of radiation, and their applications.

Keywords: Medical applications, Gamma Radiations, Atomic Nuclei

Introduction

Radiation is often considered as either ionizing or non-ionizing depending on the energy of the radiated particles. Ionizing radiation emits more than 10 eV to ionize atoms and molecules and break the chemical bonds. This is an important distinction due to the large difference in harmfulness to living organisms. Ionizing radiation is radioactive materials that emit α, β, or γ radiation, consisting of helium nuclei, electrons or positrons, and photons, respectively. Other sources include X-rays from medical radiography examinations of mesons, positrons, neutrons and other particles that constitute the secondary cosmic rays that are produced after primary cosmic rays interact with Earth's atmosphere [1]. Radiation is mainly defined as the emission or transmission of energy in the form of waves or particles through space or material medium. Electromagnetic Radiation consists with radio waves, microwaves, infrared, visible light, ultraviolet, x-rays, and gamma radiation (γ), Particle Radiation are found as the form of alpha radiation (α), beta radiation (β), proton radiation and neutron radiation, Acoustic Radiation can be exemplified as ultrasound, sound, and seismic waves and Gravitational Radiation is the radiation that takes the form of gravitational waves, or ripples in the curvature of space time [2].

Sensitivity of organisms to radioactivity

There is a wide range of sensitivity of organisms to radioactivity. Mammals are most sensitive while bacteria are most resistant especially as spores. Moreover there is a wide range of tolerance to radiation during the life cycle of an organism. Radiation sickness in humans can be caused by as little as 0.35 Gy while a dose of 6-8 Gy is lethal to nearly 100% of individuals (Donnelly et al 2010). A dose of 2 Gy may kill some insect embryos while a dose of 100 Gy is necessary to kill all adult individuals (Odum 1971). Dividing cells are generally more susceptible to radiation than resting cells. The toxicity of radionuclides depends on the absorption, distribution in the body, half-life, elimination half-time, type of radiation emitted, and their energy. Sparrow (1962), Sparrow and Evans (1961), Sparrow and Woodwell (1962), and Sparrow et al (1963) have demonstrated that sensitivity of ionizing radiation is directly proportional to the size of the cell nucleus or chromosome volume. The larger the chromosome volume the more sensitive the material is to radiation. There are also differences in radiation tolerance between wild and laboratory rodent populations. Gambino and Lindberg (1964) and Golley et al (1965) have reported that the lethal dose for 50% of some wild rodent populations is roughly twice that of laboratory white mice or white rats, likely due to the reduced variation in the latter. Radioactivity has been successfully used to sterilize certain male insect pests. Sterile males are introduced to natural populations in large numbers which mate with females. A female mates only once, and once mated with a sterile male produces no young. Introducing radiated sterile male screw-worm flies in areas where they occur successfully reduced the number of screw-worm flies, a major pest in the southern United States. For those seeking more general information on this topic see Baumhover et al (1955) Bushland (1960), Cutcomp (1967), Knipling (1960,1964, 1965, 1967) and Lawson (1967).

Radiation effects on ecosystems

Since the early 1960's there have been numerous studies on the effect of gamma radiation on ecosystems. These studies were fueled by the arms race between the Soviet Union and the United States (Stalter and Kincaid 2009). After lengthy negotiations between the two powers the SALT (Strategic Arms Limitation Treaty) was signed in 1971 and extended in 1977. With the signing of the treaty, less funding for irradiation studies was available (Stalter and Kincaid 2009). Thus most studies cited in this paper are those conducted prior to the SALT agreement of 1971. The gamma source that has been used has been either cesium 137 or cobalt 60. These include the studies of Woodwell (1962, 1965a) at Brookhaven National Laboratory, Long Island, New York, a tropical rain forest , Puerto Rico (Odum and Pigeon 1970) and the desert of Nevada (French 1965). Additional studies have been conducted in the fields and forests of Georgia (Odum and Kuenzler 1963) (Platt 1965), and Oak Ridge, Tennessee (Witherspoon 1965, 1969). Much additional work involving a portable gamma source on plant communities has been conducted at the Savanna River Ecology Laboratory, Aiken, South Carolina (McCormick and Platt 1962, McCormick and Golly 1966, Monk 1966, McCormick 1969). Stalter and Kincaid (2009) investigated community development following gamma radiation at a pine-oak forest, Brookhaven National Laboratory, Long Island, New York. The objective of this study was to compare vascular plant community change at five vegetation zones the site of Woodwell's (1962) gamma irradiated forest (Figure 1). The zones were: the dead zone where all vegetation was killed; a gramminoid Carex pensylvanica zone; an ericaceous zone; an oak dominated zone; and a control, the original oak pine forest. Radiation greater than 63,000 roentgens killed all vegetation. Carex dominated the zone receiving 27,000 to 63,000 roentgens, ericaceous shrubs, Vaccinium spp. and Gaylussacia baccata were dominant at the zone receiving 11,000 to 27,000 roentgens while oaks survived at the zone receiving 3600 to 11,000 roentgens. Upon completion of the Woodwell study in the 1970's, pitch pine (Pinus rigida) has invaded the total kill zone as bare mineral soil favors pine regeneration (Stalter and Kincaid 2009). Carex remained the dominant taxon in the original Carex zone demonstrating again that different plant species vary in their tolerance of radiation. Herbaceous plant communities may be more resistant to radiation than mature forests because many early successional species have small nuclei (Sparrow and Evans 1961) and also because herbaceous taxa like Carex pensylvanica have more below ground plant material which is shielded from gamma radiation. Sparrow (1962), Sparrow and Evans (1961), and Sparrow et al (1963) present detailed information on the relationship between nuclear volumes, chromosome numbers and relative radiosensitivity

Biological magnification of radioactive material

Radioactive material may become concentrated or "biologically magnified" during food chain transfer. Numerous biology and ecology text books include information on how living organisms take up nutrients pesticides and radioactive material and concentrate them. Because this concept is well known, we direct the reader to several early studies involving the concentration of radioactive material (See the work of Foster and Rostenbach, 1954; Hanson and Kornberg 1956; Davis and Foster 1958). Ophel (1963) reported a concentration of strontium 90 in perch flesh as 5x that of lake water while that in perch bone was 3000x! Additional information on radioecological concentration can be found in Auberg and Crossley (1958), Auberg and Hungate (1967) and Polikarpov (1966).

Effect of gamma radiation on morphological, biochemical, and physiological aspects of plants and plant products

on the basic interaction of radiation with biological systems has contributed to human society through various applications in medicine, agriculture, pharmaceuticals and in other technological developments. In the agricultural sciences and food technology sectors, recent research has elucidated the new potential application of radiation for microbial decontamination due to the inhibitory effect of radiation on microbial infestation. The last few decades have witnessed a large number of pertinent works regarding the utilization of radiation with special interest in γ-rays for evolution of superior varieties of agricultural crops of economic importance. In this review, general information will be presented about radiation, such as plant specificity, dose response, beneficial effects, and lethality. A comparison of different studies has clarified how the effects observed after exposure were deeply influenced by several factors, some related to plant characteristics (e.g., species, cultivar, stage of development, tissue architecture, and genome organization) and some related to radiation features (e.g., quality, dose, duration of exposure). There are many beneficial uses of radiation that offer few risks when properly employed. In this review, we report the main results from studies on the effect of γ-irradiations on plants, focusing on metabolic alterations, modifications of growth and development, and changes in biochemical pathways especially physiological behaviour.

Radioactive fallout

Radioactive particles that fall to the earth after above ground nuclear tests and nuclear power plant accidents are called radioactive fallout. Radioactive particles mix with the dust in the atmosphere and eventually fall to earth often thousands of miles from the initial explosion. There are two types of nuclear weapons, the fission bomb and fusion bomb or thermonuclear weapon. In thermonuclear devices, deuterium fuses to form a heavier element with the release of energy and neutrons. A fission bomb is needed to trigger the fusion reaction. The thermonuclear weapon produces more neutrons which induce radioactivity in the environment than a fission device per unit of energy released. Roughly ten percent of the energy of a nuclear weapon is in residual radiation which may become dispersed in the atmosphere (Glasstone 1957). The amount of fallout produced depends on the type of weapon, size of the weapon and also on the amount of naturally occurring material that is mixed with the radioactive material released in the explosion. Fallout patterns and intensity depend upon the direction of the wind, speed and direction of the jet stream, presence and amount of precipitation. Atomic explosions carry radioactive material high in the atmosphere where the radioactive material becomes fused with silica dust and other material present in the vicinity of the explosion. These particles are largely insoluble. The fallout particles may adhere to vegetation where they enter food chains at the primary consumer level. Fallout from Chernobyl in 1986 was deposited in Lappland (Sweden) where caribou consumed contaminated vegetation. Shifting winds also carried Chernobyl radiation particles to northern Italy where rabbit growers fed their rabbits vegetation contaminated with radioactive fallout from Chernobyl. Ultimately the rabbits were destroyed because of the high concentration of radioactive material in their flesh. There are differences in the kind of radionuclides that enter terrestrial and marine food chains. Soluble fission products, strontium 90 and cesium 137, are generally found in the highest amounts in land plants and animals. In marine systems fallout that forms strong complexes with organic matter such as cobalt 60, iron 59, zinc 65, and manganese 54 are most likely to be concentrated in marine organisms. In addition, those found in colloidal form such as cesium 134 and zirconium 95 are also found in high concentration in marine organisms. Cesium 134 is mostly from the fission products of a power reactor whereas cesium 137 can be formed during atomic power plant accidents or as a product of nuclear bomb explosions. There are additional considerations/problems associated with concentrating radioactive material entering food chains as the concentration of radioactivity is also a function of nutrient richness, and the exchange and storage capacity of soils. Nutrient poor soils and thin soils such as those found on granite outcrops act as a nutrient trap providing more radionuclides to the vegetation. For example, sheep grazing on hill pastures in England accumulated 20x as much strontium 90 in their bones than sheep pastured in deep valleys where calcium content of the soil was higher and the grasses taller (Bryant et al 1957). For additional radiological work on tracers in food chains and trophic levels see Odum and Golley (1963), Odum and Kuenzler (1963), de la Cruz (1963), Ball and Hooper (1963), Foster (l958), and Foster and Davis (1956).

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