Natural Poisons and Radioactive Toxicity

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WHAT IS RADIATION?

Radiation is the process by which energy is emitted as either particles or waves. Broadly, it can take the form of sound, heat, or light. However, most people generally use it to refer to radiation from electromagnetic waves, ranging from radio waves, though the visible light spectrum, and up through to gamma waves.

Radioactive sources were what allowed Ernest Rutherford, Marie Curie and others to conduct the first examinations of the nucleus. In the intervening century, radioactivity has revealed itself capable of a myriad of applications, and has become an invaluable source of subatomic information. The very nature of radioactivity allows scientists to trace atoms or molecules with great sensitivity.

The large diversity of radioactive elements together with the tremendous spectrum of their respective half-lives leads to many applications. Some can survive for billions of years, while others disappear within minutes. This range, from the quasi-permanent to the instantaneous, allows for radioactivity to be used in practically every sphere of human endeavour.

Radioactivity also has uses in earth science and the study of the environment. It was in these fields that uranium, potassium and rubidium allowed for an accurate estimate of the age of the Earth. Climatologists measure solar activity by seeing how much beryllium$_{10}$ produced by cosmic rays gets absorbed by the polar ice caps. Oceanographers can, through measuring the abundance of carbon$_{14}$ in the oceans, retrace the flows of ancient streams.

Ionizing radiation takes a few forms:

Alpha, beta, and neutron particles, and gamma and X-rays. All types are caused by unstable atoms, which have either an excess of energy or mass (or both). In order to reach a stable state, they must release that extra energy or mass in the form of radiation.

Alpha Radiation

Alpha radiation is a heavy, very short-range particle and is actually an ejected helium nucleus. Some characteristics of alpha radiation are:

Most alpha radiation is **not able to penetrate human skin**.

Alpha-emitting materials can be harmful to humans if the materials are inhaled, swallowed, or absorbed through open wounds.

A variety of instruments has been designed to measure alpha radiation. Special training in the use of these instruments is essential for making accurate measurements.

A thin-window Geiger-Mueller (GM) probe can detect the presence of alpha radiation.

Instruments cannot detect alpha radiation through even a thin layer of water, dust, paper, or other material, because alpha radiation is not penetrating.

Alpha radiation travels only a short distance (a few inches) in air, but is not an external hazard.

Alpha radiation is not able to penetrate clothing.

Examples of some alpha emitters: radium, radon, uranium, thorium.

Beta Radiation

Beta radiation is a light, short-range particle and is actually an ejected electron. Some characteristics of beta radiation are:

Beta radiation may travel several feet in air and is moderately penetrating.
Beta radiation **can penetrate human skin** to the "germinal layer," where new skin cells are produced. If high levels of beta-emitting contaminants are allowed to remain on the skin for a prolonged period of time, they may cause skin injury.
Beta-emitting contaminants may be harmful if deposited internally.
Most beta emitters can be detected with a survey instrument and a thin-window GM probe (e.g., "pancake" type). Some beta emitters, however, produce very low-energy, poorly penetrating radiation that may be difficult or impossible to detect. Examples of these difficult-to-detect beta emitters are hydrogen-3 (tritium), carbon-14, and sulfur-35.
Clothing provides some protection against beta radiation.

Examples of some pure beta emitters: strontium-90, carbon-14, tritium, and sulfur-35.

Gamma and X Radiation

Gamma radiation and x rays are highly penetrating electromagnetic radiation. Some characteristics of these radiations are:

Gamma radiation or x rays are able to travel many feet in air and many inches in human tissue. They readily **penetrate most materials and are sometimes called "penetrating" radiation.**

X rays are like gamma rays. X rays, too, are penetrating radiation. Sealed radioactive sources and machines that emit gamma radiation and x rays respectively constitute mainly an external hazard to humans.

Gamma radiation and x rays are electromagnetic radiation like visible light, radiowaves, and ultraviolet light. These electromagnetic radiations differ only in the amount of energy they have. Gamma rays and x rays are the most energetic of these.

X-Rays are longer-wavelength and (usually) lower energy than gamma radiation, as well.

Examples of some gamma emitters: iodine-131, cesium-137, cobalt-60, radium-226, and technetium-99m.

Neutrons

Neutrons are high-speed nuclear particles that have an exceptional ability to penetrate other materials. Of the five types of ionizing radiation discussed here, neutrons are the only one that can make objects radioactive. This process, called neutron activation, produces many of the radioactive sources that are used in medical, academic, and industrial applications (including oil exploration).

Because of their exceptional ability to penetrate other materials, neutrons can travel great distances in air and require very thick hydrogen-containing materials (such as concrete or water) to block them. Fortunately, however, neutron radiation primarily occurs inside a nuclear reactor, where many feet of water provide effective shielding.

IONIZING VS NON-IONIZING RADIATION

Radiation is generally classified ionizing or non-ionizing, based on whether it has enough energy to knock electrons off atoms that it interacts with, as well as being able to do lower-energy damage such as breaking chemical bonds in molecules. Ionizing radiation, which is caused by unstable atoms giving off energy to reach a more stable state, is more of a health threat to humans because it involves changing the basic makeup of atoms in cells, and more specifically the DNA molecules inside of cells. It does, of course, take a very strong dose of radiation to substantially damage a cell’s structure, as there can be trillions of atoms in a single cell. Most non-ionizing radiation, such as radio and microwave energy, is considered harmful only to the extent of the amount of heat energy it transfers to whatever it hits. This is, in fact, the way that microwaves cook food. UV light is unique in that while it is non-ionizing, it does have the capacity to cause harmful effects similar to what ionizing radiation can create, such as an increased risk of cancer due to damage to DNA molecules.

HOW IS RADIATION MEASURED?

The radioactivity of a substance, or how “active” it is radioactively, is measured in either curies (Ci) or Becquerel’s (Bq). Both are measures of the number of decays per second, or how often an atom in a given sample will undergo radioactive decay and give off a particle or photon of radiation. The curie (1 Ci equals about 37,000,000,000 decays per second) is named after Marie and Pierre Curie, and is equal to roughly the activity of one gram of radium, which they studied. The Becquerel is the SI unit for radioactivity. One Bq equals one decay per second. The Bq is the SI unit, though the curie remains widely used throughout the US in both government and industry.

Measuring Dose

Placing your body near a radioactive source results in exposure. To evaluate the hazard from this exposure one must compute the **absorbed dose**. This is defined as the energy imparted to a defined mass of tissue. Dose is generally not uniform over the body. A radioactive substance can be selectively taken up by different organs or tissue.

Radiation doses are often calculated in the units of **rad** (short for **r**adiation **a**bsorbed**d**ose). One rad is 100 ergs/gram, in other words, 100 ergs of energy absorbed by one gram of a given body tissue. An erg is one-ten-millionth of a joule. One hundred rad equals one Joule/kilogram (J/kg), which also equals one **Gray** (Gy), the standard international unit for measuring radiation dose.

Uses of Radiation

To benefit humankind, radiation is used in medicine, academics, and industry, as well as for generating electricity. In addition, radiation has useful applications in such areas as agriculture, archaeology (carbon dating), space exploration, law enforcement, geology (including mining), and many others.

- Medical Uses
- Academic and Scientific Applications
- Industrial Uses
- Nuclear Power Plants

The most common medical procedures involve the use of x-rays — a type of radiation that can pass through the skin.

X-rays and other forms of radiation also have a variety of therapeutic uses. When used in this way, they are most often intended to kill cancerous tissue, reduce the size of a tumor, or reduce pain. For example, radioactive iodine (specifically iodine-131) is frequently used to treat thyroid cancer.

X-ray machines have also been connected to computers in machines called computerized axial tomography (CAT) or computed tomography (CT) scanners. This helps physicians locate and identify tumors, size anomalies, or other physiological or functional organ problems.

In addition, hospitals and radiology centers perform nuclear medicine procedures. In such procedures, doctors administer slightly radioactive substances to patients, which are attracted to certain internal organs such as the pancreas, kidney, thyroid, liver, or brain, to diagnose clinical conditions.

Radiation Effects on Human

1. Acute exposure
- High dose
- Short exposure time

2. Chronic exposure
- Low dose
- Low exposure time
- Occupational radiation exposure
- Exposure from natural background radiation

Nuclear fusion and fission

Nuclear fusion and **nuclear fission** are different types of reactions that release energy due to the presence of high-powered atomic bonds between particles found within a nucleus.

In fission, an atom is split into two or more smaller, lighter atoms.

Fusion, in contrast, occurs when two or more smaller atoms fuse together, creating a larger, heavier atom.

During the final stage of World War II, the United States detonated two nuclear weapons over the Japanese cities of Hiroshima and Nagasaki on August 6 and 9, 1945, respectively. Killed 129,000–226,000 people.

Increase cancer, caused birth defects, affected brain development.

Chernobyl disaster

The Chernobyl disaster was a catastrophic nuclear accident. It occurred on 25–26 April 1986 in the No. 4 light water graphite moderated reactor at the Chernobyl Nuclear Power Plant near the now-abandoned town of Pripyat, in northern Ukrain.

237 people suffered from acute radiation sickness, of whom 31 died within the first three months

Tumors, cancer (throid, leukemia)

Alexander Litvinenko

He was a British naturalised Russian defector and former officer of the Russian FSB secret service. In 2006, he was attributed to poisoning with radionuclide polonium-210 after the Health Protection Agency found significant amounts of the rare and highly toxic element in his body.

Mushroom poisoning

Mushroom poisoning refers to harmful effects from ingestion of toxic substances present in a mushroom. These symptoms can vary from slight gastrointestinal discomfort to death. The toxins present are **secondary metabolites** produced by the fungus. Serious symptoms do not always occur immediately after eating, often not until the toxin attacks the kidney or liver, sometimes days or weeks later.

Alpha-amanitin: For 6–12 hours, there are no symptoms. This is followed by a period of gastrointestinal upset (vomiting and profuse, watery diarrhea). This stage is caused primarily by the phallotoxins and typically lasts 24 hours. At the end of this second stage is when severe liver damage begins. The damage may continue for another 2–3 days. Kidney damage can also occur. Some patients will require a liver transplant. Amatoxins are found in some mushrooms in the genus **Amanita**, but are also found in some species of **Galerina** and **Lepiota**. Overall, mortality is between 10 and 15 percent. Recently, Silybum marianum or blessed milk thistle has been shown to protect the liver from amanita toxins and promote regrowth of damaged cells

Orellanine: A few species in the very large genus **Cortinarius** contain this toxin. In humans, a characteristic of poisoning by the nephrotoxin orellanine is the long latency; the first symptoms usually do not appear until 2–3 days after ingestion and can in some cases take as long as 3 weeks. The first symptoms of orellanine poisoning are similar to the common flu (nausea, vomiting, stomach pains, headaches, myalgia, etc.), these symptoms are followed by early stages of renal failure (immense thirst, frequent urination, pain on and around the kidneys) and eventually decreased or nonexistent urine output and other symptoms of renal failure occur. If left untreated death will follow. Although there is no known antidote against orellanine poisoning, early hospitalization can sometimes prevent serious injury and usually prevent death. Some treatments make use of anti-oxidant therapy and corticosteroids to help victims recover from their renal failure.

Coprine: Coprine is metabolized to a chemical that resembles disulfiram. It inhibits aldehyde dehydrogenase (ALDH), which, in general, causes no harm, unless the person has alcohol in their bloodstream while ALDH is inhibited. This can happen if alcohol is ingested shortly before or up to a few days after eating the mushrooms. In that case the alcohol cannot be completely metabolized, and the person will experience flushed skin, vomiting, headache, dizziness, weakness, apprehension, confusion, palpitations, and sometimes trouble breathing. Coprine is found mainly in mushrooms of the genus **Coprinus**.

Muscarine: Muscarine stimulates the muscarinic receptors of the nerves and muscles. Symptoms include sweating, salivation, tears, blurred vision, palpitations, and, in high doses, respiratory failure. Muscarine is found in mushrooms of the genus Omphalotus, notably the Jack o' Lantern mushrooms. It is also found in A. muscaria, although it is now known that the main effect of this mushroom is caused by ibotenic acid. Muscarine can also be found in some Inocybe species and Clitocybe species, in particular Clitocybe dealbata, and some red-pored Boletes.

Psilocybin: Dephosphorylates into the psychoactive psilocin upon ingestion, which acts as a **psychedelic drug (LSD)**. Symptoms begin shortly after ingestion. In general, the effects include euphoria, visual and mental hallucinations, changes in perception, a distorted sense of time, spiritual experiences, and can include possible adverse reactions such as nausea and panic attacks. Some members of the genus **Psilocybe** contain psilocybin, as do some Panaeolus, Copelandia, Conocybe, Gymnopilus, and others. Some of these mushrooms also contain baeocystin, which has effects similar to psilocin.

Mycotoxin

A mycotoxin (from the Greek mykes, "fungus" and toxikon, "poison") is a toxic secondary metabolite produced by organisms of the fungus and is capable of causing disease and death in both humans and other animals. The term 'mycotoxin' is usually reserved for the toxic chemical products produced by fungi that readily colonize crops.

Examples of mycotoxins causing human and animal illness include **aflatoxin**, citrinin, fumonisins, **ochratoxin A**, patulin, trichothecenes, zearalenone, and **ergot akaloids** such as ergotamine.

Most fungi are aerobic (use oxygen) and are found almost everywhere in extremely small quantities due to the diminute size of their spores. They consume organic matter wherever **humidity** and **temperature** are sufficient. Where conditions are right, fungi proliferate into colonies and mycotoxin levels become high. The production of toxins depends on the surrounding intrinsic and extrinsic environments and these substances vary greatly in their toxicity, depending on the organism infected and its susceptibility, metabolism, and defense mechanisms.

Aflatoxin

Aflatoxins are poisonous carcinogens that are produced by certain molds (**Aspergillus flavus,** Aspergillus parasiticus) which grow in soil, decaying vegetation, hay, and grains. They are regularly found in improperly stored staple commodities such as cassava, chili peppers, corn, cotton seed, millet, peanuts, rice, sesame seeds, sorghum, sunflower seeds, tree nuts, wheat, and a variety of spices.

Animals fed contaminated food can pass aflatoxin transformation products into eggs, milk products, and meat. ***Aflatoxin B1*** is considered the most toxic and is produced by both Aspergillus flavus and Aspergillus parasiticus.

Aflatoxin B1 and B2, produced by Aspergillus flavus and A. parasiticus

Aflatoxin G1 and G2, produced by some Group II A. flavus and Aspergillus parasiticus

Aflatoxin M1, metabolite of aflatoxin B1 in humans and animals (exposure in ng levels may come from a mother's milk)

Aflatoxin M2, metabolite of aflatoxin B2 in milk of cattle fed on contaminated foods

Aflatoxin Q1 (AFQ1), major metabolite of AFB1 in in vitro liver preparations of other higher vertebrates

The presence of those molds does not always indicate that harmful levels of aflatoxin are present, but does indicate a significant risk. The molds can colonize and contaminate food **before harvest** or **during storage**, especially following prolonged exposure to a **high-humidity environment**, or to stressful conditions such as **drought**.

The metabolism of AFB1 is catalyzed by a variety of CYP450 enzymes. In human liver, CYP3A4 is an important enzyme to biotransform AFB1 to the toxic product AFB1-8,9-epoxide. In addition to CYP3A4, CYP1A2, CYP2A4 and CYP2A5 are also involved in the activation of AFB1.

The epoxide of AFB1-8,9-epoxide could conjugate with glutathione to reduce the toxicity by glutathione-S-transferase (GST). In poultry species, CYP2A6, CYP3A37, CYP1A5, and CYP1A1 are responsible for bioactivation of AFB1.

AFLATOXICOSIS

Acute toxic effects of aflatoxins are important. The United States Food and Drug Administration (FDA) action levels for aflatoxin present in food or feed is 20 to 300 ppb.

High-level aflatoxin exposure produces an acute hepatic necrosis, resulting later in cirrhosis or carcinoma of the liver. Acute liver failure is made manifest by bleeding, edema, alteration in digestion, changes to the absorption and/or metabolism of nutrients, and mental changes and/or coma.

Chronic exposure increases the risk of developing liver and gallbladder cancer, as aflatoxin metabolites may intercalate into DNA and alkylate the bases through epoxide moiety.

Chronic, subclinical exposure does not lead to symptoms so dramatic as acute aflatoxicosis.

The main target organ in mammals is the **liver**, so aflatoxicosis primarily is a hepatic disease. **Group I human carcinogen (liver).**

A regular diet including apiaceous vegetables, such as carrots, parsnips, celery, and parsley may reduce the carcinogenic effects of aflatoxin.

There is no specific antidote for aflatoxicosis. Symptomatic and supportive care tailored to the severity of the liver disease.

Ergot Poisoning

Ergotism is the effect of long-term ergot poisoning, traditionally due to the ingestion of the alkaloids produced by the **Claviceps purpurea** fungus that infects rye and other cereals, and more recently by the action of a number of ergoline-based drugs. It is also known as **ergotoxicosis, ergot poisoning and Saint Anthony's Fire.**

During the Middle Ages, **ergotism**, a severe reaction to ergot-contaminated food (such as rye bread), was common and was known as **St. Anthony's fire**. This illness was often cured by visiting the shrine of St. Anthony, which happened to be in an ergot-free region of France.

Despite serious safety concerns, ergot has been used as medicine. Women use it to treat excessive bleeding during menstrual periods, at the start of menopause, and before and after miscarriage. They also use ergot after childbirth to expel the placenta and contract the uterus. Historically, ergot was used to speed up labor, but its use was abandoned when people made a connection between the use of ergot and an increased number of stillbirths.

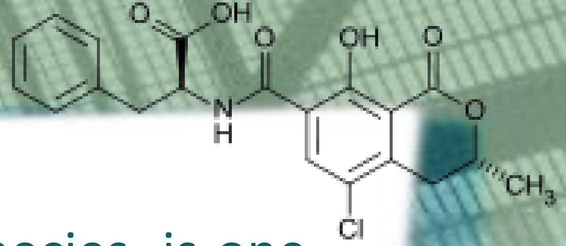
Certain chemicals in ergot are used in prescription medicines. Ergot contains chemicals that can help reduce bleeding by causing a narrowing of the blood vessels.

The symptoms can be roughly divided into **convulsive** symptoms being similar to Lysergic acid diethylamide (LSD) and **gangrenous** symptoms.

Convulsive symptoms of ergotism include painful seizures and spasms, diarrhea, paresthesias, itching, mental effects including mania or psychosis, headaches, **hallucination**, nausea and vomiting. Usually the gastrointestinal effects precede central nervous system effects.

The dry gangrene is a result of vasoconstriction induced by the ergotamine-ergocristine alkaloids of the fungus. It affects the more poorly vascularized distal structures, such as the fingers and toes. Symptoms include desquamation or peeling, weak peripheral pulses, loss of peripheral sensation, edema and ultimately the death and loss of affected tissues. Vasoconstriction is treated with vasodilators.

Ochratoxin A



Ochratoxin A, a toxin produced by different Aspergillus and Penicillium species, is one of the most-abundant food-contaminating mycotoxins. It is also a frequent contaminant of water-damaged houses and of heating ducts. Human exposure can occur through consumption of contaminated food products, particularly contaminated grain and pork products, as well as coffee, wine grapes, and dried grapes. The toxin has been found in the tissues and organs of animals, including human blood and breast milk.

Ochratoxin A is potentially carcinogenic to humans (Group 2B), and has been shown to be weakly mutagenic, possibly by induction of oxidative DNA damage.

Ochratoxin A has a strong neurotoxic effect, has an affinity for the brain, especially the cerebellum (Purkinje cells), ventral mesencephalon, and hippocampal structures.

Balkan endemic nephropathy (**BEN**), a slowly progressive renal disease, appeared in the middle of the 20th century, highly localized around the Danube, but only hitting certain households. Patients over the years develop renal failure that requires dialysis or transplantation.