الأسبوع الثالث

2.2 Radiation Sources (Natural and Artificial)

Radioactive contaminants are typically unstable radionuclide (or radioisotopes), some of them naturally occurring in the environment, such as Potassium-40 (^{40}K) and Radium-226, while others, such as Strontium-90 (^{90}Sr) and Technetium-99 (^{99}Tc), appear as a result of human activities.

The presence of several natural radionuclide such as Tritium (^{3}H) and particularly Uranium-238 (^{238}U) has been substantially enhanced in the last 5-6 decades due to various nuclear projects of either military of civil origin.

The radiation is constantly present in the natural environment and called background radiation. It can be caused by numerous sources, including the following: Cosmic rays, the effect of which strongly depends on the state of stratosphere (e.g. “ozone holes” have recently appeared);

1-Radon gas, released from the Earth's crust into the atmosphere and then attaching to airborne dust and other particulate (granular, powder) materials, that human beings might ingest and inhale;

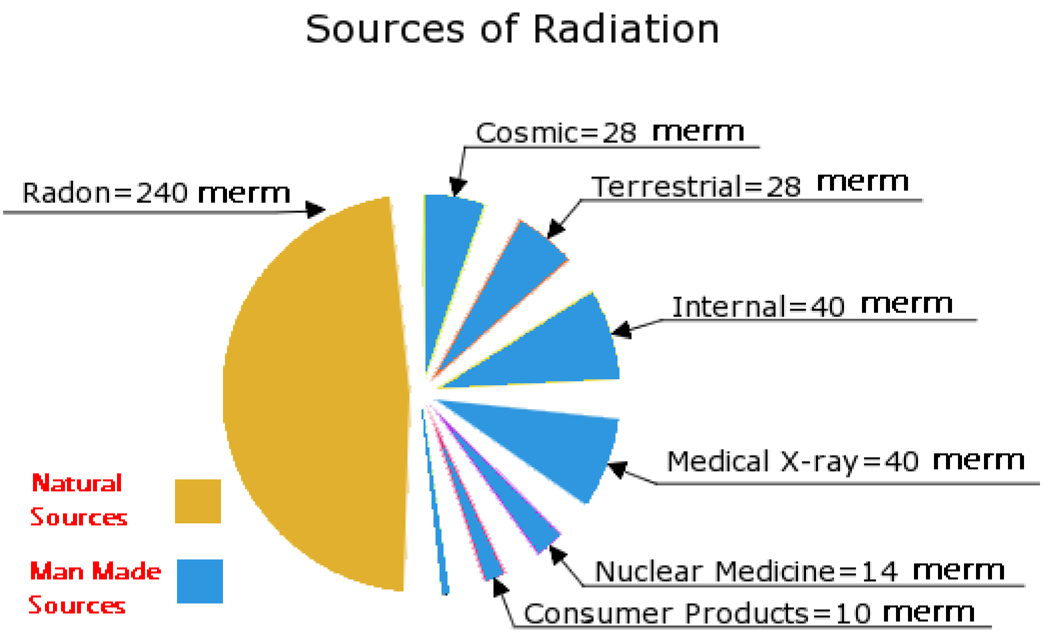
2-Radionuclide’s, present in natural minerals, stones and therefore in building materials;

3-Mineral hot springs, containing mostly Radium 226 and small amounts of other radio-isotopes which are rather useful and used by people as spas.

4-Artificial sources of background radiation used in radiological imaging and radiation therapy cannot be excluded from this list.

Average annual human exposure to ionizing radiation in millisievert (mSv)				
Radiation source	**World**			**Remark**
Inhalation of air	1.26			mainly from radon, depends on indoor accumulation
Ingestion of food & water	0.29			(K-40, C-14, etc.)
Terrestrial radiation from ground	0.48			depends on soil and building material
Cosmic radiation from space	0.39			depends on altitude
sub total (natural)	2.40			sizeable population groups receive 10-20 mSv
Medical	0.60			world-wide figure excludes radiotherapy; US figure is mostly CT scans and nuclear medicine.
Consumer items	-			cigarettes, air travel, building materials, etc.
Atmospheric nuclear testing	0.005			peak of 0.11 mSv in 1963 and declining since; higher near sites
Occupational exposure	0.005			world-wide average to all workers is 0.7 mSv, mostly due to radon in mines US is mostly due to medical and aviation workers.

Chernobyl accident	0.002			peak of 0.04 mSv in 1986 and declining since; higher near site
Nuclear fuel cycle	0.0002			up to 0.02 mSv near sites; excludes occupational exposure
Other	-			Industrial, security, medical, educational, and research
sub total (artificial)	0.61			
Total	3.01			**millisievert per year**



2.3 Radiation Dose and Units

Exposure is a measure of ionization produced in air by X- rays or gamma rays passing through a mass (*m*) of dry air at standard temperature 0 ºC and pressure of 1 atm. When passing through the air, the beam produces positive ions whose total charge is *q*. Exposure is defined as the total charge per unit mass of air.

$$Exposure\ (X) = q/m$$

The SI unit for exposure is Coulombs per kilogram (C/kg). However, the first radiation unit to be defined was the Roentgen (R), with *q* expressed in Coulombs and *m* in kilograms (kg). The exposure in Roentgen is given by

$$X(R) = 2.5 * 10^{-4} q/m$$

Thus, when X-rays or γ-rays produce an exposure of one Roentgen, a positive charge of $2.5x10^{-4}$C is produced in 1kg of dry air, and one roentgen equal:-

$$1\text{R} = 2.5 * 10^{-4} C/Kg$$

For biological purposes, the absorbed dose is a more suitable quantity, because it is the energy absorbed from radiation per unit mass of absorbing material.

Absorbed dose = (Energy absorbed) / (Mass of absorbing material)

The SI unit of absorbed dose is Gray (Gy), which is a unit of energy divided by a unit of mass: Gy =J/kg. Another unit often used for absorbed dose is rad (rd), an acronym for ‘radiation absorbed dose’. The rad and Gray are related by 1rad = 0.01Gray.

Rad is the amount of energy, which the human body absorbs. However, equal doses of different types of radiation may not have the same effects on the body; for instance, a dose of alpha particles is more damaging than the same dose of gamma rays or beta particles. To compare the damage caused by different types of radiation, relative biological effectiveness

(RBE) is used, also called the quality factor (QF). The relative biological effectiveness of particular type of radiation compares the dose of that radiation needed to produce a certain biological effect, to the X- rays needed to produce the same biological effect.

RBE= [the dose that produces a certain (reference) biological effect /the dose of X-rays radiation that produces same biological effect].

The RBE depends on the ionizing radiation and its energy, as well as the type of tissue being irradiated.

Type of radiation	**RBE**
200-keV X-rays	1
X- rays	1
β-particles (electrons)	1-2
Protons	10
α- particles	10-20
slow neutrons	2
fast neutrons	10

Table. 2.1. Typical RBE values for different kinds of radiation.

The RBE is often used in connection with the absorbed dose to reflect the character of damage produced by radiation. The product of the absorbed dose in rad and RBE is the biologically equivalent dose (DE).

Biologically equivalent dose (in rem) =Absorbed dose in (rad) * RBE

$$DE=D*RBE$$

The unit for the biologically equivalent dose is the rem. The rem is the unit of radiation which accounts for the different effects of different types of radiation. In order to calculate the equivalent dose in rem, the absorbed dose must be established. If the unit of the absorbed dose (D) is Gray, then the unit of DE is Sievert, or if the unit of the absorbed dose (D) is rad, then the unit of DE is rem.

where: 1Sievert =100 rem.