

Radiation and units

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There are multiple units for radiation: grays, sieverts, the DARI, and so on. Which units should one use and why should they be used?

OLD UNITS:

curie 3.7×10^{10}
disintegrations per second

rad The exposure from one
röntgen in soft body tissue.

rem One rem is the dose
from exposure to one röntgen.

röntgen One röntgen produces
one electric charge (1.6×10^{-19} C)
per 10^{-6} m³ of dry air at 0 ° C and
atmospheric pressure. This
corresponds to an energy loss of
0.0877 joule per kilogram of air.

working level A unit of radioactive exposure to 1.3×10^5 MeV per liter of air (or about 3.7 disintegrations per liter of air, or about 3700 disintegrations per cubic meter of air).

There are a lot of different units, and while some are clearly different, others seem like they're measuring the same thing.

“NEW” UNITS:

(There are just three.)

Activity

The rate of nuclear disintegrations is known as the activity. Activity is the total number of disintegrations in a sample. It is measured using the *becquerel* (Bq), which is one disintegration per second. A gram of radium, for example, produces about 3.7×10^{10} disintegrations per second.

Exposure

Activity by itself is not enough to allow determination of the health effects of radiation, because just knowing something decays does not tell us what effect it will have. Clearly, if a lot of energy is deposited into some matter by a particle such as a fission decay product that it is passing through, it will do more damage to the matter than one that deposits little energy. The *gray* (Gy), which is a measure of absorbed energy, is the unit of exposure (officially, “absorbed dose”) from gamma radiation losing 1 J/kg of material (such as tissue).

Dose $(D = Q E)$

The *sievert* (Sv) is equivalent in biological effect to 1 gray of gamma rays.

Why isn't this just the gray?

The amount of energy deposited per unit length, known as *linear energy transfer (LET)*, is a measure of the ionizing ability of radiation. For electrons and gamma or x rays, 1 sievert results from exposure to ~ 1 gray. For alpha particles at fission energies, 1 sievert results from exposure to ~ 1/20 gray. For typical protons and neutrons, 1 sievert results from exposure to ~ 1/10 gray.

Using the units:

At home:

An apartment-dweller in a concrete structure receives an excess annual dose of about 0.25 mSv. People living in houses made with stone, concrete, or masonry, receive an additional annual dose is 70 to 250 μSv .

A wooden house provides an activity density of 70 $\text{Bq}/\text{m}^2/\text{h}$, while in a masonry house, it is 90 $\text{Bq}/\text{m}^2/\text{h}$.

In the air:

An airline passenger flying at 8 km over the U.S. gets a dose at a rate of about 5 to 8 $\mu\text{Sv}/\text{h}$. Airline crew members and frequent flyers receive doses of around 5 to 6 mSv/yr.

At work:

A person working in a nuclear power plant would probably receive a dose of 2.5 mSv/yr . In 1999, the greatest measured annual dose to any nuclear worker was ~230 mSv. This occurred at a Westinghouse Electric Company fuel fabrication facility.

The DARI

Dose Annuelle due aux Radiations Internes

There is an inescapable dose coming from human bones and tissue from internal radioactive nuclei (about 90% is potassium-40, most of the remainder is carbon-14, and there are smaller contributions from other elements). Charpak and Garwin propose to use this to invent a new unit of dose.

They calculate internal dose to be 0.17 mSv. They round this to 0.2 mSv as the DARI.

$$1 \text{ DARI} = 0.2 \text{ mSv}$$

The ICRP implies that exposure to one DARI carries a probability of incurring lethal cancer of 7×10^{-6} .

If a lethal cancer shortens life by 16 years on average, Charpak and Garwin calculate that a DARI dose would shorten a life by about one hour.

The annual dose from the environment is around 5 to 10 DARI, the dose from a chest x ray is 5 DARI, a CAT scan delivers a dose of 40 DARI, and 25,000 DARI is lethal.

The dose allowed nuclear workers (500 DARI), has the same effect that these workers would get from smoking one-half a pack of cigarettes per day.

A French citizen's life is shortened by about 6 minutes per year because of the 80% French dependence on nuclear energy, minuscule in comparison to the loss from supplying this energy from coal-fired plants.

I hope you will use
the three independent
SI radiation units

becquerel

gray

sievert

from now on,

and maybe use the

DARI

when speaking to the
public.