Other applications of Nuclear

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Since the discovery of the phenomenon of radioactivity about a hundred years ago, numerous applications of nuclear reactions, ionizing radiation and radioactive substances have been developed. Radioactivity is used today in many different sectors, with electricity production and medicine perhaps being the best known. But in addition, radioactive isotopes are also used in the food sector, for domestic applications, in agriculture, industry, space travel, archaeology, and so on. In this chapter, we'll take a closer look at some of those applications.

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1 Radio sterilization in different sectors

When **ionizing food,** the products are exposed to X-rays or gamma rays to destroy the microorganisms present. Of course, the food products themselves do not become radioactive! They are not contaminated or activated by the radiation to which they are exposed, because the energy of the X or gamma rays used is insufficient to make the products themselves radioactive. Many products are sterilized in this way: our pink and grey **shrimps**, frog legs, **herbs**, some **frozen products**, corks of luxury beers or wines, etc. The technique also allows to slow down the germination of plants such as potatoes, onions or garlic. In the United States, radio sterilization is used to ensure the food safety of hamburgers. In addition, irradiation is also a widely used sterilization technique for **surgical equipment**, **prostheses and** other **pharmaceutical** or **cosmetic products**.

Destroying pathogenic germs and extending the shelf life of food products

Thanks to the **radio sterilization of insects** (or sterile insect technique), the screwworm fly (Cochliomyia hominivorax), a parasite that plagued cattle, could be eradicated in the 70s in Florida and Texas. More recently, the technique was also used in the fight against the screwworm fly in Egypt and Libya.

The control technique consists of releasing a large population of males, who were made sterile by irradiation, into the natural population. This ensures that the females will produce far fewer offsprings and it is therefore a way to combat a harmful insect on a large scale without the use of toxic agents (pesticides).

As in Radiation Therapy, the sources for Radio Sterilization are gradually replaced with accelerator driven gamma fields. Here the bremsstrahlung effect of slowing down accelerated particles is used to created strong and tuneable irradiation fields. With the benefit that the irradiation stops when the accelerator is no longer powered. IBA from Louvain-la-Neuve is commercializing the Rhodotron.

2 Domestic applications

Perhaps the best-known **household application** was the **smoke detector** which works on the basis of a radioactive closed source. There are different types of non-radioactive detectors, but short-range ionization by means of alpha particles is the fastest way to detect smoke before it is visible.

Tritium is still used in luminescent paints (watches, dials), replacing radium.

3 Earth Sciences

In **agronomy** or agriculture, nuclear techniques have contributed to a more rational use of soil water resources. Based on the knowledge that fast neutrons are slowed down by the hydrogen atoms in water, the **humidity meter** or neutron probe can determine the humidity level of the soil very precisely.

Radioactivity is also used in **earth or geosciences**. With the help of uranium, potassium or rubidium, one can **determine the age of the earth**. Climatologists measure the amount of beryllium-10 produced by the cosmic rays in the atmosphere and stored in the ice sheets of the poles. The higher the beryllium concentration, the lower the solar activity. Beryllium-10 has a half-life of 1.6 million years and is one of the products that arise from the rupture (spallation) of oxygen and carbon nuclei under the impulse of cosmic rays. So, it gives us precise information about the evolution of the atmosphere going very far back in time.

Oceanographers can use the **carbon 14** content in seawater to trace the trajectory of an ocean current. Thanks to carbon-14, it is also possible to go back tens of thousands of years in the past. Carbon, which is part of the carbon gas compound present in our atmosphere, is very dispersed in our environment. That carbon consists mainly of the stable carbon-12 and for a very small part of carbon-14, which is radioactive and has a decay time of 5,730 years (carbon-14 is permanently produced by the cosmic rays in the nitrogen present in the air). The different exchanges between the atmosphere and the "living world" (respiration, photosynthesis, food) balance the ratio between the amount of carbon-12 and carbon-14. But once an organism dies, the amount of carbon-14 in that organism is no longer renewed as exchanges with the external world stop. The ratio between carbon-14 and carbon-12 will gradually decrease due to radioactive decay, and the ratio between the two isotopes allows to determine its age long after the death of an organism (carbon dating). The less carbon-14 is present in a sample, the longer the organism is dead. The carbon-14 method revolutionized archaeology because it allows **objects or places** to be dated back to about 40,000 years ago. To delve even further back in time, other methods based on radioactive decay, such as the potassium-argon ratio, are utilized.

Thanks to methods based on radioactivity, the **remains of the past** can be accurately identified, analysed and studied. We can determine its authenticity and extract a wealth of archaeological or historical information from it and thus learn more about the way our ancestors lived. Moreover, precisely because of their age, these remains are often very fragile; radioactive methods allow them to be investigated but not altered or damaged, in such a way that many future generations will still be able to admire them.


Petrified skeleton of a horse, found near Oudenburg, near Ostend

4 Industrial applications

Radioactive tracers can also be used to monitor how certain substances move through the production process in a chemical plant or to detect leaks in underground pipes. They also play a role in the (quality) control of many industrial manufacturing processes. These are always non-destructive controls that do not disrupt the manufacturing cycle. For example, in the petrochemical sector in refineries, a small amount of argon-41 atoms is added in the phase in which the heavy fuel atoms are 'cracked' (process in which molecules and alkanes split into smaller molecules by heating, often in the presence of a catalyst). In this way, the engineers follow the production process, make improvements, and thus ensure that motorists ultimately fill up with better quality fuel at the pump. In large cement factories, the cisterns that supply the raw materials pass through a neutron source. The gamma rays from the deexcitation of the activated cores provide information about the exact composition of the mixture, making it possible to permanently adjust and produce cement of a constant quality.

In much higher radiation doses, radioactivity is also used to modify the **mechanical and chemical properties** of materials. For example, there is an industrial process similar to that for the restoration of old furniture, in which soft wood is turned into a parquet as hard as stone. These highly resistant parquet floors are used, for example, in places that are used very intensively, such as airports, public buildings, large shops, museums, etc.

There are many other industrial applications in which radioelements are used in **closed** source, so that only the radiation can escape and the matter from the radiation source itself does not contaminate the environment; this is referred to as irradiating but non-contaminating sources. Before 1940, only the radium sources used in medicine existed. After the Second World War, with the rise of nuclear reactors and the first cyclotrons, it became possible to create new sources of radiation and many new industrial applications emerged, often in domains where there were no equivalent alternatives without the use of radioactivity existed.

Industrial radiography is a non-destructive method of analysis. X-rays or gamma-rays are used to check the quality of metal parts, welds, casts, etc. For field or portable use radioelements in closed sources are often preferred. The most commonly used isotopes are Cobalt-60, Iridium-192, Selenium-75, Thulium-170, Ytterbium-169 and Cesium-137. Neutron beams are also used in industrial neutrography, for example to examine aircraft wings for traces of corrosion.

Radiography of a pipeline connection, checking for any cracks

Industrial measurement, analysis and testing equipment is very diverse, and often uses one of the following isotopes: Cesium-137, Cobalt-60, Americium-241, Krypton-85, Strontium-90, Promethium-147 and Radium-226, whether linked to Beryllium or not. We can distinguish between the following families:

1. Transmission measurements, where densities or fluid flows are measured (e.g. in the brewing sector);
2. Retro diffusion measurements, measuring humidity or corrosion;
3. Reaction measurements, which use phenomena such as X-fluorescence and analyse the constituents of certain materials (e.g. paint) or ores, or the thickness of certain layers.

In the **operation of wells**, various radiation sources are used to determine the density, porosity, humidity and hydrocarbon content of certain geological structures or materials. Cesium-137 is the most used isotope in this context, with neutron sources such as americium/beryllium, plutonium/beryllium or radium/beryllium. Four different techniques are used:

1. Gamma measurements, to identify rocks by their natural radiation (uranium, thorium, potassium);
2. Neutron measurements, to evaluate the porosity of the rocks;
3. Gamma/gamma measurements, used to detect gases;
4. Neutrons/gamma measurements, to map the amount of chlorine and salts.

Antistatic equipment is used to overcome electrostatic problems in sectors where sparks and dust particles can cause major problems, such as in the electronics sector. This equipment often uses radiation sources (alpha rays) with large dimensions, mainly Am-241, Ra-226 and Po-210.

Table: Overview of industrial application of radioisotopes in closed source.

Application	Radio-element	Activity of the source
Industrial radiography	192Am 60Co (137Cs, 170Tm, 169Yb)	0,1-5 TBq 0,1-5 TBq
Drillings	241Am/Be 137Cs (252Cf)	1-800 GBq 1-100 GBq
Humidity detectors	241Am/Be 137Cs (252Cf, 226Ra/Be)	0,1-2 GBq 400 MBq
Transfer measurements	137Cs	0,1-40 GBq
Density measurements	137Cs 241Am	1-20 GBq 1-10 GBq
Level gauges	137Cs 60Co (241Am)	0,1-20 GBq 0,1-10 GBq
Thickness measurement	85Kr 90Sr (14C, 147Pm, 241Am)	0,1-50 GBq 0,1-4 GBq
Antistatic equipment	241AM 210Po (216Ra)	1-4 GBq 1-4 GBq
Reaction measurements	55Fe 109Cd (238Pu, 241Am, 57Co)	0,1-5 GBq 1-8 GBq

Lastly, we conclude this brief overview with a mention of **space** applications, an area not often associated with radioactivity but equally fascinating. While this overview does not cover all uses of radioactivity beyond medicine and electricity production, the role of radioisotopes in space is worth highlighting. Since the 1960s, radioactive sources have been utilized to generate electricity aboard spacecraft. Thermoelectric generators were developed to convert the energy released from radioactive decay into electricity, with plutonium-238 being a common choice due to its reliability for periods of around five years.