# RSDetection™

## Environmental radiation monitor

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# Introduction

Gamma (γ) emitting radioactive active material has multiple applications. Nuclear reactors and medical uses, industrial applications, oil and gas exploration are only some of the examples that use this material. In such settings, it is important to monitor and survey this radioactive material to avoid non-essential exposure to the public and the environment. The RSDetection is the latest of Reuter-Stokes line of gamma (γ) radiation monitors designed to do just that. It is unsurprising to know that radioactive material has proven to be useful in multiple applications.

Besides powering nuclear reactors, radioactive isotopes are used for medical purposes, such as Xrays or radiation therapy. Both rely on the penetrating properties of high energy electromagnetic radiation.

Other industries have also found different ways to use radioactive material. Oil and gas exploration uses the backscattering properties of both gamma (γ) rays and neutrons to evaluate the environmental properties deep underneath the Earth's surface. Gamma (γ) radiation can also be used for gauging material properties.

Evaluating the thickness of asphalt when building roads or determining the moisture content in paper pulp are other examples where radioactive materials can be used in different sectors.

# Environmental radiation monitoring

It is important to monitor and survey the use of radioactive materials to avoid losing control of them and potentially causing non-essential exposure to the public and the environment. There are three different types of gamma (γ) emitting radioactive material. These include:

- **Natural background radiation**: Radioactive isotopes are naturally present in the environment. The gamma (γ) emission coming from these natural isotopes constitutes a background dose rate that humans are exposed to daily. This dose rate can vary depending on the activity and type of environment that any given person encounters. For example, the type of material used in the construction of our homes can slightly influence the natural background gamma (γ) dose rate.
- **Man-made radioactive isotopes**: Some isotopes are made in nuclear reactors or are created for medical or industrial purposes. At times, some of this radioactive material "escapes" or gets lost in the environment. Whether it is from nuclear catastrophes, like Chernobyl or Fukushima, or a simple mishandling of an Xray machine, these escaped isotopes spread radioactivity into the environment.
- **Cosmic radiation**: Cosmic rays include particles such as electrons, protons, and heavier nuclei. Their sources are not yet known, but we expect them to be both galactic and extragalactic. The Earth's atmosphere is constantly bombarded by these particles (essentially protons and α particles). When these particles collide with the atmosphere's nucleus, it generates secondary cosmic radiation, composed mainly of muons, electrons, neutrons and highly energetic gamma (γ) rays. After creation of secondary radiation, these particles cascade toward the Earth's surface.
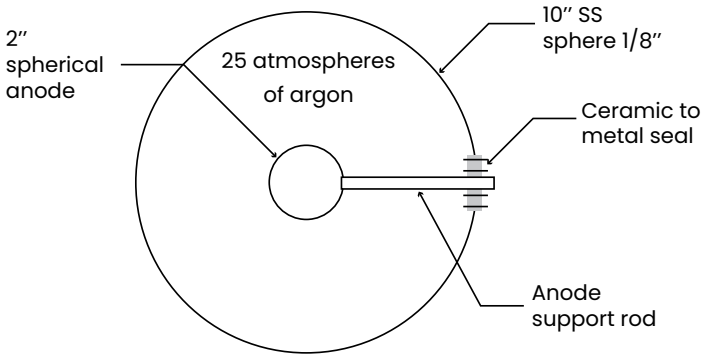
## Field spectroscopy vs. dose-rate measurement

There are two different techniques used for in-situ environmental radiation monitoring:

**Field gamma (γ) spectroscopy** consists of acquiring the energy spectra of radionuclide present in the environment. This technique stands out because it can identify the different radio-isotopes contributing to the dose. On the other hand, this tedious technique can take many hours to generate measurements making it difficult to detect any dose rate modification. The complexity to analyze the results adds to this technique's complexity.

**Dose-rate measurement** monitors human exposure caused by external sources of gamma (γ) radiation. The measurement is online and provides near immediate results. The lack of isotope identification, however, makes it difficult to distinguish between the natural background, the man-made sources, and the cosmic radiation.

# RSDetection product specifications



2″ spherical anode — 25 atmospheres of argon — 10″ SS sphere 1/8″ — Ceramic to metal seal — Anode support rod

The sensor's high-pressure ionization chamber (HPIC) was designed to achieve the best balance between sensitivity, energy response, stability, measurement range, and accuracy. The detector consists of a 25cm stainless-steel outer sphere that contains approximately 25 atmospheres of argon and an inner 2 inch anode.

In operation, a high-voltage bias of -400 volts is applied to the outer shell, while keeping the anode at ground potential. When gamma (γ) rays pass through the detector, they interact with the steel wall and argon gas to generate a current on the anode. The amount of current produced is primarily a function of the number of photons, the gamma (γ) ray energy, and the incident direction of the photons.

The RSDetection operates in current mode. The gamma (γ) dose rate up to 1 Sv/hr can be measured without any of saturation of the electrometers. Reuter-Stokes' HPIC contains more than 191L effective argon volume with <±5 nSv/hr minimum detectable, which makes it the most sensitive dose rate meter on the market.

One of the HPIC's strengths is its angular response to incident photons. The RSDetection's spherical design delivers <2% angular dependence over the 4π symmetry.

# Terrestrial radiation
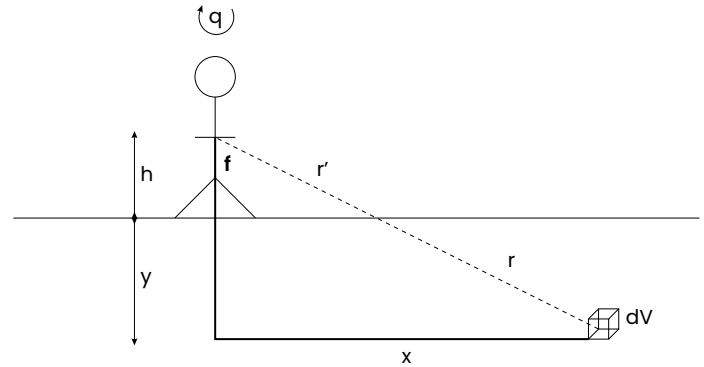


Terrestrial radiation is generated by all of the radioactive elements present in the soil, both natural and man-made. The equivalent dose and the effective dose are determined from the amount of incoming radiation per unit volume area. The figure gives a schematic representation of the flux of radiation $\Phi_i$ coming from a volume unit $dV$. The soil contains an activity A (in Bq/kg) of particles with energy $E_i$ (in J) of intensity $I_i$

$$\Phi_i = \int_V \frac{A}{4\pi(r^1+r)^2} e^{-\mu_{ssoil}r} e^{-\mu_{sair}r^1} dV$$

where $\mu_{ssoil}$ and $\mu_{sair}$ are the absorption coefficient of the soil and of the air, respectively, which varies for gamma (γ) rays of different energies. Because the integration is done over the whole area, the flux of incoming radiation becomes

$$\Phi_i = \int_{\varphi=0}^{\frac{\pi}{2}} \int_{\theta=0}^{2\pi} \int_{r=0}^{8} \frac{A}{4\pi(r^1+r)^2} e^{-\mu_{ssoil}r} e^{-\mu_{sair}r^1} (r^1+r)^2 \sin\varphi \, dr \, d\theta \, d\varphi$$

where φ is the axial angle and θ is the radial angle. When integrating this equation, the flux of radiation through a $dV$, becomes

$$\Phi_i = \frac{A}{2\mu_{ssoil}} \int_{\varphi=0}^{\frac{\pi}{2}} e^{-\frac{\mu_{sair}}{\cos\varphi}} \sin\varphi \, d\varphi$$

The resulting absorbed dose rate

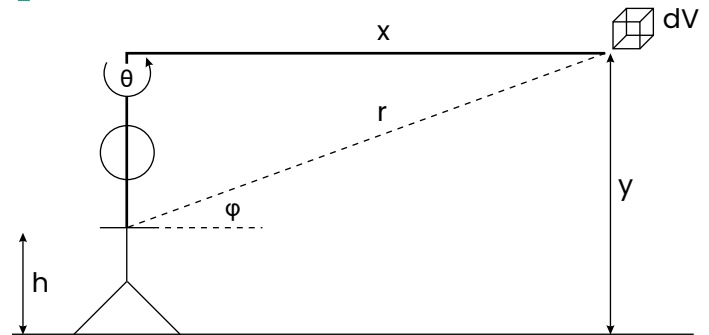$$\dot{D} = \sum_i E_i I_i \cdot \Phi_i$$

With < ±5 nSv/hr minimum detectable dose rate limit, the RSDetection can detect less than 8:82 $10^{11}$ Bq/kg of Cs-137 contamination in soils. It also detects less than 1:067 x $10^{11}$ Bq/kg of Co-60. The figure above shows the minimum detectable limits for contaminated soils at different energies.
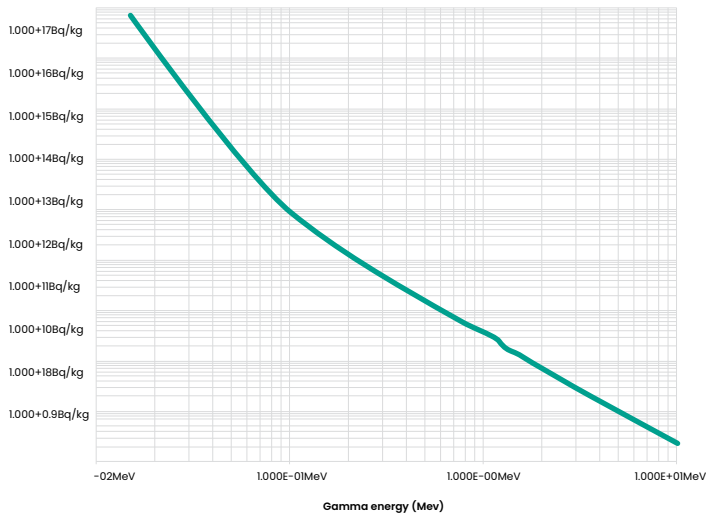


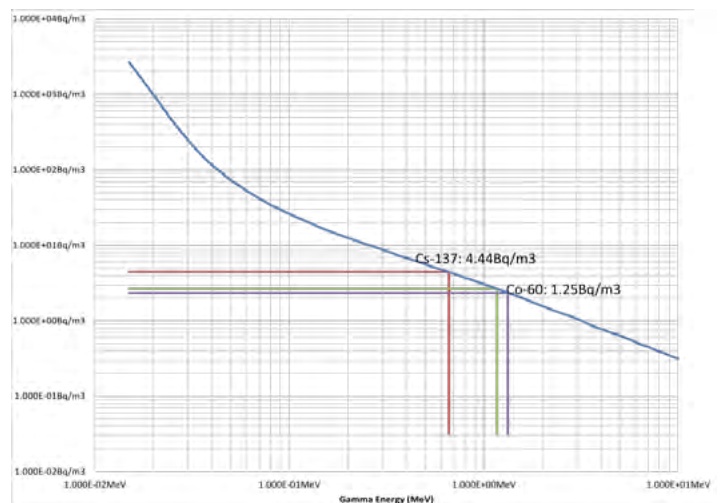Minimum detectable limit for contaminated soils

# Radioactive plume



We will consider the scenario where radioactive elements are suspended in the air. The figure gives a schematic representation of the flux of radiation $\Phi_i$ coming from a volume unit *dV*. The soil contains an activity A (in Bq/m³) of particles with energy $E_i$ (in J) of intensity $I_i$

$$\Phi_i = \int_V \frac{A}{4\pi r^2} e^{-\mu_{sair} r} dV$$

where $\mu_{sair}$ is the absorption coefficient of the air, which varies for gamma ($\gamma$) rays of different energies. Because the integration is done over the whole area, the flux of incoming radiation becomes the resulting absorbed dose rate
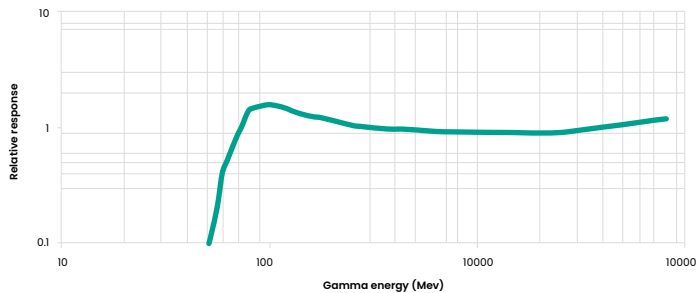
$$\dot{D} = \sum_i E_i I_i \cdot \Phi_i$$

With < ±5 nSv/hr minimum detectable dose rate limit, the RSDetection can detect less than 1:045 x 4.44Bq/m3 of Cs-137 and less than 7:5409 x 1.25Bq/m3 of Co-60. The figure below shows the minimum detectable limits for contaminated soils at different energies.



Minimum detectable limit for contaminated soils

# Energy response and sensitivity



Both naturally occurring and man-made radionuclides can emit gamma (γ) radiation ranging from a few keV up to many MeV. The Reuter-Stokes high pressure ionization chamber is filled with approximately 25atm argon, which makes it very sensitive to gamma (γ) rays ranging from ~ 50keV up to more than 20MeV. The RSDetection sensor has a flat energy response over this wide energy range.

When operated in current mode, it can also measure dose rates up to 1 Sv/hr without saturating the electrometers.

# Contribution of cosmic radiation

As noted earlier, cosmic rays include such particles as electrons, protons, and heavier nuclei. While their source is unknown, we believe it's both galactic and extragalactic. The Earth's atmosphere is constantly bombarded by the primary particles (essentially protons and α particles). The collisions of these particles with the atmosphere's nucleus generates secondary cosmic radiation, composed mainly of muons, electrons, neutrons and highly energetic gamma (γ) rays. After creating secondary radiation, these particles cascade toward the Earth's surface.

The Earth's atmosphere acts as a shield against cosmic radiation. The greater the layer of atmosphere, the more it absorbs cosmic radiation and increases the shield. Therefore, cosmic radiation increases with altitude.

The mean equivalent dose absorbed for charged cosmic particles (Hc) over yearly period in function of the altitude (z):

$$H_c = (45.87 \frac{\mu Sv}{yr})e^{-\frac{z}{0.6\ km}} + 177.731e^{\frac{z}{2.2\ km}}$$

The mean equivalent dose absorbed for cosmic neutrons (Hn) over yearly period as a function of the altitude (z):

$$H_n = \begin{cases} (20\frac{\mu Sv}{yr})e^{\frac{z}{0.962\ km}} & \text{for } z < 2km \\ (39.6\frac{\mu Sv}{yr})e^{\frac{z}{1.432\ km}} & \text{for } z > 2km \end{cases}$$

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