Environmental Radioactivity Monitoring
Introduction

We live in a world in which radiation is present everywhere, coming either from natural or artificial sources.

Natural isotopes are found in earth. The most known are Uranium ($^{238}$U, $^{235}$U), Thorium ($^{232}$Th), Potassium ($^{40}$K) and their daughters. Natural isotopes are detected not only in soil and minerals, but also in water, air, living organisms, food and building materials.

Artificial isotopes are man-made, they are produced for nuclear technology and nuclear sciences applications in biology, energy, health etc.

The Greek Atomic Energy Commission (GAEC) is the national competent authority for the environmental radioactivity monitoring throughout the country. GAEC is also responsible to maintain and update the national environmental radioactivity database. Moreover, it is responsible to notify the government, the European Commission and IAEA in case of increased radioactivity levels in the environment.

EURATOM Treaty Articles 35 and 36 make provisions for the systematic monitoring of radioactivity levels in air, water and soil and the relevant record keeping. EC inspections verified that Greece fulfills its obligations towards these articles.

The environmental radioactivity monitoring throughout Greece is achieved through different types of measurements (telemetric network, laboratory, in-situ) performed by GAEC and a network of collaborating laboratories. GAEC is responsible for the planning, coordination and evaluation of these measurements.

GAEC’s policy regarding the environmental radioactivity monitoring programme is based on the principle of transparency, given the public’s interest on environmental issues. Indicatively, the data recorded by the telemetric network of environmental radioactivity monitoring are easily accessed by the public at GAEC’s website.
1. Telemetric network for environmental radioactivity monitoring

The telemetric network for environmental radioactivity monitoring in Greece consists of:

- 24 stations monitoring the total gamma dose rate in air. Their operation is based on photons detection in the energy area from 50 keV to 10 MeV and for dose rates in the range of 10 nSv/h to 1 mSv/h.

- 3 aerosol monitoring stations. These stations are equipped with air pumps (6m³/h) and detectors for gamma spectroscopy and total α/β radiation measurements.

The telemetric stations have been installed across the country in a way that the radioactivity levels are continuously monitored and the early notification in case of radioactive contamination is assured.
The telemetric network records every ten minutes, 24 hours per day, the radioactivity levels. It is an alarm system in case of exceeding certain levels, keeping measurements on hourly basis for later review. Each station is supported by software for data collection and storage in GAEC’s database. This database is connected with GAEC’s website, where the mean daily values are presented, as well as with the European network EURDEP (European Radiological Data Exchange Platform).

Relevant websites:
http://www.eeae.gr
http://eurdep.jrc.ec.europa.eu
2. Laboratory measurements

GAEC performs measurements on environmental samples, in order to quantify the radionuclides concentration in different environmental media.

a) Environmental samples measurements

Low background gamma spectrometry

GAEC is equipped with two low background gamma ray spectroscopic systems based on High Purity Germanium detectors (HPGe). The one is a p-type HPGe detector of relative efficiency 70% and the other a broad energy HPGe detector of relative efficiency 50%. The detection efficiencies are determined using standard sources with different sample geometries and densities.

By the gamma spectroscopic analysis samples are measured for:

a) import, export or use of foodstuff, soil, building materials etc.

b) inspections of workplaces with increased natural radioactivity levels (soil, solid resi-
dues, air filters, sediments).

The measurements performed by GAEC with γ- spectrometry are accredited according to the requirements of the ELOT EN ISO/IEC 17025 standard (Certificate No. 117_{(a)}).

**alpha spectrometry**

Actinides (thorium, uranium, plutonium, americium and curium), as well as Polonium-210 and Radium-226, are isolated and measured by means of alpha spectrometry.

Depending on the sample type, the isolation is usually involving three steps:

a) sample preparation and preconcentration, achieved by evaporation, microwave digestion, wet and dry ashing

b) chemical separation of the radionuclides, achieved by liquid-liquid extraction and anion/ cation exchange

c) electrodeposition of the sample onto stainless steel plates.

The measuring equipment used in GAEC’s laboratory is a fully automated and integrated alpha spectroscopic system (Alpha Analyst, Canberra), consisting of 12 Passivated Implanted Planar Silicon (PIPS) detectors with 600 mm^{2} active area. To transfer the data from the Analyst to an external database, a computer software has been developed. This software reads automatically the ASCII report files from the Analyst; the data are stored in the
above mentioned database.

The most common samples are:

- drinking water, surface water, spa water, sea water
- environmental samples from sites with elevated NORM concentrations
- samples from phosphogypsum depositions for uranium and radium isotopes detection.
**Total α/β radiation measurements and Tritium determination**

The total α/β measurements are performed by a gas flow proportional counter in antico-incidence quard G-M detection. The samples that are usually measured by total α/β are:

- smear tests samples of radioactive sources
- drinking water samples, according to the Directive 98/83/EK of EU Council
- samples of surface and underground water
- air filters.

Tritium concentration measurements are performed by a liquid scintillation counter of Quantulus type.

**β) Radon gas concentration measurements**

Radon is a natural radioactive gas, well known as the main source of exposure to natural radiation. The risk associated to radon is due to its radioactive decay products, which have short half-life and irradiate lung tissues with alpha particles, increasing the lung cancer risk.

Globally, the mean annual dose attributed to radon is estimated 1, 2 mSv (almost the 50% of the total annual dose to the population due to natural radiation). However, the radon concentration, and thus the dose, differentiates from region to region and even from building to building in the same area.

Radon is a colorless, odorless and inactive gas. Outdoors its concentrations are low, as it disperses in the air. Radon gas is penetrating to the indoor atmosphere mainly through the floor from the ground and through buildings cracks. The indoor radon concentration depends on various factors, such as the geology of the area, the flow rate from ground,
the building materials, the existing ventilation system, the kind of substructure and the height of the building.

Radon concentration measurements are performed in dwellings and workplaces using radon passive dosemeters (track-etched detectors). The dosemeters are placed in the building according to the guidelines given for a period of time from three months to one year. After this period, dosemeters are returned to GAEC in order to be measured.

Electret type detectors are used in cases that short term measurements are required. A similar technique is used for radon concentration determination in the water.

GAEC, taking into consideration the available data, as well as its own measurements results, publishes updated radon maps in cooperation with the European Commission. Measurements are performed either on request or in cooperation with local authorities in the framework of the National Radon Survey.
In-situ measurements

In-situ measurements are usually included in the environmental radioactivity monitoring programme.

In situ measurements are performed for:

- the qualitative and the quantitative determination of a potential radiological contamination,
- the radiological inspection of scrap metals,
- the in-situ characterization of the materials and
- the characterization of places during decommissioning activities.
GAEC is equipped with an energy autonomous mobile laboratory including germanium detector 35%, lead shielding for low background γ spectrometry measurements, detectors for dose measurement and surface contamination.

Furthermore, it has four portable γ-ray spectroscopic systems based on germanium detectors of relative efficiency 10%, 20%, 35% and 35%.

These systems are calibrated using sources, analytical techniques and Monte Carlo simulations for various geometries, e.g. pipes and metal objects of different size and shape.
4. Environmental surveys

Laboratory measurements performed in the framework of the national environmental programme include:

1. **radioactivity levels controls in surface and underground water.** The natural radioisotopes concentration is determined in rivers waters crossing the border with neighbouring countries. Underground waters close to phosphogypsum deposition areas are also monitored.

2. **inspections in workplaces and materials with increased natural radioactivity levels.** This category includes measurements in spas, mines, caves, underground workplaces and play where materials with increased natural radioactivity levels are produced or stored, e.g. phosphoric acid production units, phosphogypsum depositions.

Radiological studies regarding the use and the deposition of natural occurring radioactivity materials have been performed by GAEC:

- during the decommissioning of an abandoned phosphoric acid production unit in the area of Drapetsona
- for the licensing of a phosphoric acid production unit in Kavala
- in phosphogypsum deposition areas (Kavala, Thessaloniki, Sxisto).
Additionally to the national environmental survey program, GAEC performs radioactivity measurements upon request. For example it performs measurements in building materials, drinking water, food etc.

**National Radiation Protection Database**

GAEC maintains the National Radiation Protection Database, where all the results of the radioactivity measurements performed in the country, are stored.
5. Collaborations - Intercomparisons

GAEC participates in intercomparisons organized by international organizations and scientific networks, in order to certify the applied radioactivity measurements methods. Systematically participates in the intercomparisons exercises of the following organizations:

- World Health Organization
- ALMERΑ
- International Atomic Energy Agency
- PROCORAD (Association for the Promotion of Quality Controls in Radiotoxicological bioassay)
- BfS (Bundesamt für Strahlenschutz)
- European Commission

In emergency situations, GAEC is supported by a network of 11 collaborating Research Centers and Universities laboratories, in order to perform large scale environmental samples’ analysis. For harmonisation and quality assurance purposes, intercomparison exercises are organized by GAEC. The network of collaborating laboratories consists of:

- NCSR "Demokritos", Institute of Nuclear Technology & Radiation Protection, Environmental Radioactivity Laboratory
- Foundation for Research and Technology, Radioactivity Measurements Laboratory
- Hellenic Center for Marine Research (HCMR), Institute of Oceanography
- National Technical University of Athens, School of Mechanical Engineering, Nuclear Engineering Department
- Aristotle University of Thessaloniki, Faculty of Engineering, Department of Electrical and Computer Engineering, Nuclear Technology Laboratory
- Aristotle University of Thessaloniki, Physics Department, Nuclear Physics and Elementary Particle Physics Division
- Demokritos University of Thrace, Department of Electrical and Computer Engineering, Nuclear Technology Laboratory
- University of Patra, Nuclear Technology Laboratory
- University of Ioannina, Department of Physics, Nuclear Physics Laboratory
- University of Ioannina, Medical School, Medical Physics Laboratory
- Technical University of Crete, Sciences Department, Analytical and Environmental Chemistry Laboratory