Environmental Radioactivity Monitoring for Earth Sciences at the INFN-Gran Sasso National Laboratory, Italy

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Within the framework of the INFN scientific experiment ERMES (Environmental Radioactivity Monitoring for Earth Sciences) radon (Plastino and Bella, 2001), radiocarbon (Plastino *et al.*, 2001; Plastino and Kaihola, 2004) and tritium (Plastino *et al.*, 2007) were monitored inside the INFN-LNGS as well as new detectors independent of the environmental noise parameters such as temperature, acid concentrations, humidity, and air pressure (Plastino *et al.*, 2002) were developed and tested. The Uranium groundwater monitoring was carried out from June 2008 with the aim to better define its contribution to the neutron background at the INFN-LNGS (Plastino *et al.*, 2009), as well as to check the radon groundwater transport processes through the overthrust fault (Plastino *et al.*, 2010; Plastino *et al.*, 2011). High Purity Germanium (HPGe) gamma-ray spectroscopy, Liquid Scintillation Counting (LSC) spectrometry, and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) have been characterised for Environmental Science applications by ERMES at the INFN-LNGS.

Ultra low-level LSC spectrometry for Radiocarbon and Tritium was performed to study the efficiency and background related to the measurement site (Plastino *et al.*, 2001). Cosmic-ray background and its variation have been removed in the INFN-LNGS by its 1,400m rock overburden and stable, high-performance liquid scintillation counting conditions are obtained when any remaining variable components of the environmental background are eliminated. Guard detector efficiency in C-14 background reduction is 8% at the INFN-LNGS, while 80% is observed on the surface (Plastino and Kaihola, 2004). The cosmic noise reduction observed at the INFN-LNGS makes it possible to perform high-precision C-14 measurements and to extend the present maximum dating limit from 58,000 to 62,000 BP (5 mL, 3 days of counting) (Plastino *et al.*, 2001) as well as to improve the minimum detectable activity (MDA) for H-3 to 0.04 Bq kg^{-1} or $\leq$ 0.4 TU (Plastino *et al.*, 2007).

Thorium and Uranium at trace levels had to be measured by ICP-MS and the tuning of the instrument was optimized in order to reach high sensitivity, stable signal, and low background. Nevertheless, ICP-MS cannot be used to analyse the radioisotopes following Uranium in the natural radioactive decay chain due to their extremely small concentration. Therefore, some samples were filtered and analysed by means of HPGe gamma-ray spectroscopy (Plastino *et al.*, 2012). Using this technique the gamma active radionuclides in the Uranium chain can be assessed, in particular the subchain of Radium: due to the different chemical behaviour of Uranium and Radium in water, it is important to know whether these two radionuclides are in secular equilibrium.

ERMES applied to Fluid Earth Physics, particularly to lagrangian atmospheric transport modeling and oceanic benthic boundary layer confirmed the unique opportunity to perform radioactivity measurements in an ultra low level background environment such as LNGS-

INFN as well as the fundamental support by INFN-GRID for developing numerical modeling for fluid dynamics in atmosphere and groundwater of interest in nuclear non-proliferation also (Etiope *et al.*, 2006; Plastino *et al.*, 2010; Schoeppner *et al.*, 2012; Tsabaris *et al.*, 2012).

The experiment ERMES was the *incipit* for a comprehensive synergic activity to realize an ultra-low level background laboratory at the INFN-LNGS for Environmental Sciences (Solid and Fluid Earth Physics) and Nuclear Metrology with a privileged open access to the other researches fields (Astroparticle Physics, Nuclear Safety, Safeguards, Nuclear Forensics, and Nuclear non-proliferation). This is the aim of the Environmental Radioactivity Monitoring for Earth Sciences-WOrld Reference Laboratory and new Developments (ERMES-WORLD).

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