ENVIRONMENTAL RADIOACTIVITY

2010

BOOK OF ABSTRACTS

ROME 25th-27th OCTOBER

NEW FRONTIERS AND DEVELOPMENTS

ACCADEMIA NAZIONALE DEI LINCEI

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CONFERENCE PROGRAMME

25th October 2010

9:00am-9:30am	**Prof. Luciano Maiani** *President of the Italian National Research Council*	Nicola Cabibbo, Physicist and Science Manager
9:30am-9:45am	**Prof. Lamberto Maffei** *President of the Accademia Nazionale dei Lincei* **Prof. Roberto Petronzio** *President of the Italian National Institute of Nuclear Physics*	Welcome Speeches
Keynote Lectures I	**Frontiers in Science**	
9:45am-10:30am	**Prof. Carlo Rubbia** *CERN and National Institute of Nuclear Physics, Italy*	The future of fission breeding reactors
10:30am-11:15am	**Prof. Werner Burkart** *International Atomic Energy Agency, Vienna, Austria*	Nuclear Sciences: sustainable contribution to the United Nations millennium development goals
Session I	**Underground Physics**	
11:45am-12:15pm	**Prof. Gianpaolo Bellini** *(Invited)* *University of Milano and INFN Milano, Italy*	Geoneutrinos
12:15pm-12:30pm	**Prof. Wolfango Plastino** *University of Roma Tre and INFN Roma Tre, Italy*	Uranium groundwater anomalies at LNGS: from the neutron flux background to the geodynamic processes

Session II	**Accelerator Mass Spectrometry**	
2:00pm-2:30pm	**Prof. William E. Kieser** *(Invited)* *University of Ottawa, Canada*	Fluoride sample matrices and reaction cells – new capabilities for isotope measurements in Accelerator Mass Spectrometry
2:30pm-2:45pm	**Dr Alfredo Galindo-Uribarri** *Oak Ridge National Laboratory, USA*	Pushing the detection limits of rare isotopes using Accelerator Mass Spectrometry
2:45pm-3:00pm	**Prof. Manuel Garcia-Leon** *University of Sevilla, Spain*	Environmental radioactivity measurements with accelerators: AMS at CNA
3:00pm-3:15pm	**Dr Mariaelena Fedi** *University of Florence and INFN Florence, Italy*	Applications of radiocarbon measurements in environmental studies at LABEC, Florence
3:15pm-4:30pm	**Poster Session I**	
Session III	**Environmental Physics**	
4:30pm-5:00pm	**Prof. Herbert Lettner** *(Invited)* *University of Salzburg, Austria*	Age determination in cryoconites with artificial and natural radionuclides
5:00pm-5:15pm	**Dr Abdulghani Shakhashiro** *International Atomic Energy Agency Vienna, Austria*	Environmental radioactivity measurements: challenges and lessons learned from the IAEA analytical proficiency testing 2005-2010
5:15pm-5:30pm	**Dr Matthias Laubenstein** *INFN Gran Sasso National Laboratory, Italy*	Environmental radioactivity measurements within the ERMES experiment at the ultra low background facility STELLA

5:30pm-5:45pm	**Prof. Giuseppina Immè** *University of Catania and INFN, Catania, Italy*	Radioactivity measurements in volcano-tectonic area for geodynamic process study
5:45pm-6:00pm	**Dr Maria A. Wasserman** *Institute of Radioprotection and Dosimetry-CNEN, Rio de Janeiro, Brasil*	The application of geotechnological tools for the construction of ^{137}Cs vulnerability maps in Brazilian soils

26th October 2010

Keynote Lectures II	**Frontiers in Science**	
9:00am - 9:45am	**Prof. Francesco Calogero** *University of Roma La Sapienza and INFN Roma, Italy*	Prospects of nuclear proliferation, or of transition to a nuclear-weapon-free world
9:45am - 10:30am	**Prof. William C. Burnett** *Florida State University, Tallahassee, USA*	Natural radon and radium isotopes as tracers in the environment
Session IV	**Groundwater-Seawater Interactions**	
11:00am-11:30am	**Dr Matthew A. Charette** *(Invited)* *Woods Hole Oceanographic Institution, USA*	Radionuclide tracers of submarine groundwater discharge on an ocean island (Guam)
11:30am-11:45am	**Dr Michael Schubert** *Helmholtz Centre for Environmental Research-UFZ, Leipzig, Germany*	The kinetics of the water/air phase transition of radon and its implication on on-site radon-in-water detection
11:45am-12:00pm	**Dr Christos Tsabaris** *Hellenic Centre for Marine Research, Anavyssos, Greece*	Study of submarine groundwater discharge by radio-tracer techniques at Kalogria bay, SW Peloponnissos, Greece
12:00pm-12:15pm	**Prof. Yasunori Mahara** *Kyoto University, Japan*	Groundwater residence time estimated from ^{4}He accumulated rate calibrated by using cosmogenic and subsurface produced ^{36}Cl
12:15pm-12:30pm	**Dr Rachid El Mrabet** *National Center for Energy, Sciences and Nuclear Techniques (CNESTEN), Rabat, Morocco*	A new technologic development for remote radiological monitoring and early detection of environmental risks in the Strait of Gibraltar

Session V	**Marine Radioactivity**	
2:00pm-2:30pm	**Dr Hartmut Nies** *(Invited)* *International Atomic Energy Agency, Monaco*	Nuclear analytical techniques in marine studies at the IAEA Marine Environment Laboratories
2:30pm-2:45pm	**Dr Galina Lujanienė** *SRI Center for Physical Sciences and Technology, Vilnius, Lithuania*	Pu, Am and Cs sorption behaviour in the Baltic Sea
2:45pm-3:00pm	**Dr Fernando P. Carvalho** *Nuclear and Technological Institute, Sacavém, Portugal*	^{210}Po as a tracer of energy transfer in marine food chains
3:00pm-3:15pm	**Dr Nikolaos Evangeliou** *NCSR Institute of Nuclear Technology-Radiation Protection, Athens, Greece*	The dispersion of ^{137}Cs in a shallow Mediterranean embayment (Saronikos Gulf – Elefsis Bay) in seasonal scale, estimated inventories and residence times
3:15pm-4:30pm	**Poster Session II**	
Session VI	**New Analytical Technologies**	
4:30pm-5:00pm	**Prof. Xiaolin Hou** *(Invited)* *Risø National Laboratory for Sustainable Energy, Roskilde, Denmark*	ICP-MS for low-level radionuclide analysis
5:00pm-5:15pm	**Dr Salvatore Frullani** *National Institute of Health, Rome, Italy*	SNIFFER: an aerial platform for real time measurements of contamination in the plume phase of a nuclear emergency
5:15pm-5:30pm	**Dr Mikael Hult** *EC-JRC Institute for Reference Materials and Measurements, Geel, Belgium*	Quantification of ^{238}U in environmental samples using gamma-ray spectrometry

5:30pm-5:45pm	**Dr Yasunori Hamajima** *Kanazawa University, Japan*	Reduction of cosmic ray components on Ge detector utilizing thin plastic scintillators and wavelength shifting fibers for anticoincidence
5:45pm-6:00pm	**Prof. Lucio Calcagnile** *University of Salento and CEDAD Laboratory, Italy*	Studies of industrial emissions by accelerator-based techniques at CEDAD

27th October 2010

Keynote Lectures III	**Frontiers in Science**	
9:00am - 9:45am	**Prof. Walter Kutschera** *University of Vienna, Austria*	Counting atoms rather than decays - the power of Accelerator Mass Spectrometry to study environmental radioactivity
9:45am - 10:30am	**Dr Francois Bréchignac** *Institute for Radioprotection and Nuclear Safety, France*	Environment protection: the current challenge in radioecology
Session VII	**Isotope Oceanography**	
11:00am-11:30am	**Prof. Katsumi Hirose** *(Invited)* *Sophia University, Tokyo, Japan*	Distribution of ^{137}Cs in the South Pacific and Indian Ocean waters: results of the SHOTS project
11:30am-11:45am	**Dr Marcus Christl** *ETH, Zürich, Switzerland*	^{236}Uranium in ocean water samples
11:45am-12:00pm	**Dr Roberta Delfanti** *ENEA, La Spezia, Italy*	Anthropogenic radionuclides in the Mediterranean Sea: space and time-distribution, mass-balance and future trends
12:00pm-12:15pm	**Prof. Pavel P. Povinec** *Comenius University of Bratislava, Slovakia*	Investigation of circulation of water masses in the southern Indian Ocean using radionuclide tracers
12:15pm-12:30pm	**Dr Alexandra Ioannidou** *Aristotle University of Thessaloniki, Greece*	Activity size distribution of ^{7}Be in association with trace metals and their deposition on the sea

Session VIII	**Radioecology**	
2:00pm-2:30pm	**Prof. Pier R. Danesi** *(Invited)* *IUSS, University of Pavia, Italy*	Radiological conditions in South Iraq where depleted uranium munitions were used
2:30pm-2:45pm	**Dr Pavol Vojtyla** *CERN, Geneva, Switzerland*	Environmental challenges of high energy/intensity hadron accelerators
2:45pm-3:00pm	**Dr Mikhail Iosjpe** *Norwegian Radiation Protection Authority, Østerås, Norway*	Evaluation of environmental sensitivity of the marine regions
3:00pm-3:15pm	**Dr Borut Smodiš** *Jožef Stefan Institute, Ljubljana, Slovenia*	Radioecology studies in the vicinity of closed uranium mine
3:15pm-4:30pm	**Poster Session III**	
Session IX	**Radioecology**	
4:30pm-4:45pm	**Dr Alexander Nikitin** *SI Research and Production Association - Typhoon, Obninsk, Russia*	Up-to-date content of long-lived artificial radionuclides in the Tom and Ob rivers in the area influenced by discharges from Siberian chemical combine
4:45pm-5:00pm	**Dr Sergey N. Lukašenko** *National Nuclear Center of the Republic of Kazakhstan, Kurchatov, Kazakhstan*	Semipalatinsk Nuclear Test Site. Current state and prospects
5:00pm-5:15pm	**Dr Sang-Han Lee** *Korea Research Institute of Standards and Science, Daejeon, Korea*	Distribution of plutonium and americium in the soils from Korea
5:15pm-5:30pm	**Dr Ashraf E.M. Khater** *King Saud University, Riyadh, Saudi Arabia*	Radioecological impacts of agricultural activities on sandy soil in arid environment

5:30pm-5:45pm	**Prof. Madan M. Sharma** *Kuwait University, Kuwait*	Radiological impact of Gulf wars on agricultural areas in Kuwait
5:45pm-6:00pm	**Dr Alexander Kryšev** *SI Research and Production Association - Typhoon, Obninsk, Russia*	Comparative analysis of doses to aquatic biota in water bodies impacted to radioactive contamination

ORAL PROGRAMME

ABSTRACTS

FRONTIERS IN SCIENCE

THE FUTURE OF FISSION BREEDING REACTORS

C. RUBBIA

CERN and National Institute of Nuclear Physics, Italy

NUCLEAR SCIENCES: SUSTAINABLE CONTRIBUTION TO THE UNITED NATIONS MILLENNIUM DEVELOPMENT GOALS

W. BURKART

International Atomic Energy Agency, Vienna, Austria

PROSPECTS OF NUCLEAR PROLIFERATION, OR OF TRANSITION TO A NUCLEAR-WEAPON-FREE WORLD

F. CALOGERO

University of Roma La Sapienza and INFN Roma, Italy

NATURAL RADON AND RADIUM ISOTOPES AS TRACERS IN THE ENVIRONMENT

W. C. BURNETT

Florida State University, USA

While environmental radioactivity is often most concerned with radiation protection, the existence of low-level non-equilibrium activities of naturally-occurring radioisotopes in the environment can be exploited to help understand how the world works. Geophysical applications using such isotopes in the past have included earthquake prediction, horizontal and vertical mixing rate studies in the ocean, air-sea gas exchange fluxes, and many more. Over the past decade, there has been a marked increase (often driven by technological advances) in the application of short-lived radium isotopes (^{223}Ra and ^{224}Ra), radon (^{222}Rn), and thoron (^{220}Rn) in marine and fresh

water systems. This presentation will demonstrate and provide examples of how these radioisotopes can be used as tracers to determine: (1) residence times and mixing rates in coastal areas and embayments; (2) experimental determination of gas exchange from the sea to the atmosphere; and (3) evaluation of groundwater discharge into both coastal marine and aquatic systems.

A recent application of the use of thoron ($t_{1/2}$ = 56s) has shown that it can be used to prospect for and locate areas of enriched natural radioactivity (NORM) in water supply systems. Thus, these radionuclides can also serve a useful purpose in the field of radiation protection as well as geophysical studies.

COUNTING ATOMS RATHER THAN DECAYS - THE POWER OF ACCELERATOR MASS SPECTROMETRY TO STUDY ENVIRONMENTAL RADIOACTIVITY

W. KUTSCHERA

University of Vienna, Austria

In our usual perception, radioactivity is connected with radiation. While it is true that radioactive atoms eventually decay by emitting some radiation which facilitates their detection, radioactive atoms can also be detected by mass spectrometry – before they decay.

In a given time period, the longer the half-life the less atoms decay. As an example, in one milligram of contemporary organic carbon we have about 60 million ^{14}C atoms. Due to the half-life of 5730 years, only about one ^{14}C atom decays per hour. On the other hand, we can easily collect a few percent of all the ^{14}C atoms per hour with Accelerator Mass Spectrometry (AMS), i.e. about one million ^{14}C atoms. Even though it was known long ago, that in principle counting atoms rather than decays would be a much more sensitive way of detecting long-lived radioisotopes, the minute isotope ratios to be measured (e.g. $^{14}C/^{12}C = 1.2x10^{-12}$) did not allow a detection by standard mass spectrometry. AMS, however, provided the means to measure isotope ratios down to 10^{-16}, thus opening the possibility to study many cosmogenic and anthropogenic radioisotopes at these ultra-low abundances. This talk will attempt to convey the power of AMS to tackle many interesting question in different domains of our environment.

ENVIRONMENT PROTECTION: THE CURRENT CHALLENGE IN RADIOECOLOGY

F. BRÉCHIGNAC

Institute for Radioprotection and Nuclear Safety, France

Born in the fifties together with the emergence of nuclear technologies, radioecology is a multifaceted scientific discipline which addresses environmental issues relevant to radioprotection. For a long time, the major focus, strengthened by the occurrence of the Chernobyl accident, has been to work out environmental transfers through the environment to feed the needs of human radioprotection. This quite anthropocentric initial scope of radioecology is now under profound evolution, especially driven by the growth of society's concern over environmental issues as arising form the re-boost of nuclear industry meant to overcome global warming issues and to face the future energetic demands. The new focus evolving is on protection of the environment per se, requiring radioecology to move towards adopting a more ecocentric view capable of assessing ecological risk mediated by ionising radiation.

The central issue consists in reaching an ability to understand the effects of radiation on the environment components, from individual organisms up to populations of species and ecosystems, together with their interaction with the abiotic compartments. Such radiation effects have been subjected to numerous studies in the past decades, but essentially focused on individual organisms exposed to high level and acute dose rates of external γ irradiation. The resulting overall knowledge therefore still proves to be very fragmented, with poor understanding of 1) the impact of chronic exposures to internal irradiation accumulated within living organisms in the long run, over several generations, and 2) their consequences on populations in terms of disturbance of ecosystem structure and functions. Large gaps also remain with respect to the diversity of animal and plant species.

These shortcomings are obviously influencing the system of radiological protection of the environment which is currently under development. Dominated by operational goals, it is driven by simplification and emphasises conceptual and methodological approaches that are readily accessible today: a concept based upon reference organisms supported by traditional toxicological data on individual organisms. Whilst there are immediate advantages to this approach (pragmatism, consistency with other approaches in use for man and biota), there are also clear limitations which need to be acknowledged and further considered. The first probably, is to rely on effects data gathered almost exclusively for individual organisms to meet protection goals which are usually set at population and ecosystem levels. One can mention a few others: uncertainties generated by the need for various extrapolations (from lower to higher levels of biological organisation, …), unability to grasp impairments of ecosystem processes, trans-generational impacts propagated via genomic instability, indirect effects mediated through trophic interactions or disruption of ecological balances.

Such limitations have already been faced in other fields of environmental protection against other stressors, pushing a number of environment professionals to assign stronger emphasis on more systemic approaches. This leads in particular to advocating the need to boost scientific and methodological approaches featuring the ecosystem concept. The ecosystem approach indeed, as illustrated by the pioneer work under the international convention on biodiversity, will provide more efficient ability to meet the objectives of environment protection.

SESSION I

UNDERGROUND PHYSICS

GEONEUTRINOS

G. BELLINI*

University of Milano and INFN Milano, Italy
**on behalf of BOREXINO Collaboration - Gran Sasso National Laboratory, Italy*

The heat present within the Earth is due in large part to radioactive decays. The only way to detect their presence in the Earth mantle is to detect the antineutrinos emitted in these processes (geoneutrinos). Their rate and distribution along the mantle can produce important insights in the Earth models and in the study of the heat distribution in the mantle.

Due to the low energy of the geoneutrino spectrum, the detectors, which can proceed to this study, need a very low radioactive level in the all components.

The Borexino experiment, at Gran Sasso Laboratory (Italy), succeeded in reaching unprecedented radioactive purity allowing the study of the low energy neutrinos from the Sun, from the Earth, from the nuclear reactors and from other possible sources. In particular Borexino reached the first real evidence (4.2) of geoneutrinos.

Similar evidence has been reached recently by Kamland experiment (Japan), but due to the presence of many nuclear reactors in Japan and to the relatively relevant radioactive background in the detector, the geoneutrino detection is more difficult.

Both the Borexino and Kamland results are compared with the Earth models: BSE, minimum and maximum radiogenic.

URANIUM GROUNDWATER ANOMALIES AT LNGS: FROM THE NEUTRON FLUX BACKGROUND TO THE GEODYNAMIC PROCESSES

W. PLASTINO*

University of Roma Tre and INFN Roma Tre, Italy
**on behalf of ERMES Collaboration - Gran Sasso National Laboratory, Italy*

The possible sources analyzed up to now for the neutron flux background at the Gran Sasso National Laboratory are the natural radioactivity in the rock, the concrete, as well as the induced part coming from interaction of cosmic ray muons with the rock or the detector material itself. Water was considered only as moderator in concrete, due to its variable concentration and its radioactivity as additional source for neutron flux modulation. Therefore, the water-rock interaction and its spatial-temporal variation induced by hydrological pattern of the Gran Sasso aquifer are taken into account.

Furthermore, monitoring of chemical and physical groundwater parameters has been carried out worldwide in seismogenic areas with the aim to test possible correlations between their spatial and temporal variations and strain processes. Uranium groundwater anomalies were observed during the preparation phases of the recent L'Aquila earthquake of 6th April 2009 in the cataclastic rocks near the overthrust fault crossing the deep underground Gran Sasso National Laboratory. The obtained results suggest that uranium may be used as a potential strain indicator of geodynamical processes occurring before the seismic swarm and the main earthquake shock.

SESSION II

ACCELERATOR MASS SPECTROMETRY

FLUORIDE SAMPLE MATRICES AND REACTION CELLS – NEW CAPABILITIES FOR ISOTOPE MEASUREMENTS IN ACCELERATOR MASS SPECTROMETRY

W. E. KIESER[1], X.-L. ZHAO[1], J. ELIADES[2] AND A. E. LITHERLAND[2]

[1]*IsoTrace Laboratory, University of Ottawa, Canada*
[2]*IsoTrace Laboratory, University of Toronto, Canada*

A major strength of Accelerator Mass Spectrometry (AMS) in the analysis of low concentrations of isotopes and rare elements is the ability to eliminate molecular isobar interferences. This strength does not extend universally to interferences from atomic isobars, except in the well know cases of ^{14}C – ^{14}N, ^{26}Al – ^{26}Mg and, to a certain extent, ^{129}I – ^{129}Xe. Furthermore, the universality of AMS is limited by the requirement to form negative ions of the analyte for tandem acceleration. Two new technologies have recently been developed at IsoTrace which provide a wide range of solutions to both these limitations:

The earlier use of analyte-fluoride compounds in the ion source improved the analysis of ^{40}Ca, with simpler sample preparation, good ion currents and some degree of suppression of the ^{40}K isobar. However, the simple addition of the analyte material to a matrix of PbF_2 in the ion source target results in large ion source currents, even simpler sample preparation and an intriguing isobar selectivity based on the number of fluorine atoms in the molecular anion selected [1].

The use of radio-frequency quadrupole ion guides and ion-gas reaction cells in the path of the beam of rare isotopes provides an additional range of highly effective analytical strategies. This has recently been demonstrated for the reduction of $^{36}S^-$ in beams of $^{36}Cl^-$ by over six orders of magnitude and for the reduction of $^{40}KF_3^-$ in beams of $^{40}CaF_3^-$ by three orders of magnitude. The latter example benefits greatly from the use of both these techniques [2].

This paper will present an overview of these technologies and discuss some potential new applications for analyses which have not previously been possible with AMS. It will conclude with a description of how these are fitted in to the new Canadian Centre for Accelerator Mass Spectrometry (AMS) at the University of Ottawa.

[1] X.-L. Zhao, A.E. Litherland, J. Eliades, W.E. Kieser and Q. Liu, Studies of anions from sputtering I: Survey of MFn–, Nuclear Instruments and Methods B 268 (2010) 807-811

[2] W. E. Kieser, J. Eliades, A. E. Litherland, X-L Zhao, L. Cousins and S J Ye, The low-energy Isobar Separator for Anions: Progress Report, Radiocarbon 52 (2010) 236-242

PUSHING THE DETECTION LIMITS OF RARE ISOTOPES USING ACCELERATOR MASS SPECTROMETRY

A. GALINDO-URIBARRI[1], N. COTZOMI[2], M. JANZEN[3], Y. LIU[1] AND E. PADILLA-RODAL[2]

[1]*Oak Ridge National Laboratory and University of Tennessee, USA*
[2]*Universidad Nacional Autónoma de México, Mexico, Mexico*
[3]*University of Tennessee, USA*

Research on the occurrence, transfer and distribution of radioactivity in natural systems will benefit from pushing further the detection limits of accelerator mass spectrometry (AMS). This technique is used to perform ultra-sensitive measurements of concentrations of rare isotopes in samples placed in the ion source of an accelerator system. The sensitivity of AMS is among the highest of any analytical technique now available. A key advantage of the technique is that it requires very small samples of material. The method consists of counting individual atoms that have been ionized, accelerated to high energies in (generally) a tandem Van de Graff accelerator, then selected and identified. This technique has important applications for environmental and biological monitoring, the study of ocean circulation patterns, radioactive waste, nuclear physics, nuclear safeguards, stewardship science, and counter-terrorism issues. AMS systems have been used to measure isotopic ratios for specific elements to levels many orders of magnitude lower than in most conventional mass spectrometers.

We are using the highest operating voltage electrostatic accelerator in the world, the 25-MV Tandem from ORNL, as a prototype facility to aid in the development of new AMS methods such as photodetachment of negative ions [1]. These techniques will broaden the range of radionuclide that can be detected at ultra-low levels. The 25 MV Tandem at ORNL offers major advantages compared to lower voltage machines in the detection and characterization of many AMS isotopes. By using this machine for ^{36}Cl we have pushed the limit of sensitivity of the important AMS isotope ^{36}Cl demonstrating that this isotope can be measured at the levels required for a tracer in oceanography [2]. I will describe the on-going research activities at the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory highlighting current approaches aimed at the studies of environmental sciences (oceanography, rock erosion and fuel cycles).

[1] A. Galindo-Uribarri et al., Nucl. Instr. Meth. B 268 (2010) 834.

[2] A. Galindo-Uribarri et al., Nucl. Instr. Meth. B 259 (2007) 123.

ENVIRONMENTAL RADIOACTIVITY MEASUREMENTS WITH ACCELERATORS: AMS AT CNA

M. GARCÍA-LEÓN, E. CHAMIZO, I. GÓMEZ, J. M. LÓPEZ-GUTIÉRREZ AND F. J. SANTOS

University of Sevilla, Spain

Accelerator Mass Spectrometry is a powerful analytical technique which has proven to be very useful in many fields. Regarding Environmental Radioactivity, AMS can comfortably compete with traditional radiometric techniques especially for long-lived radionuclides and when the sample amount is low. At the Spanish National Center for Accelerators (CNA) a 1MV tandem Cockcroft-Walton based mass spectrometer is working since some few years ago. Applications of the system include Environmental Radioactivity studies and the goal of this paper is the description of such as measurements. Thus, the determinations currently carried out of Pu-isotopes and ^{129}I in different sample matrices as sediments, air filter, rainwater, seaweed and others will be presented. Sample preparation methods have been developed for the specific studies. They will be also described.

Work supported by the Spanish Science and Innovation Ministry project FIS2008-01149

APPLICATIONS OF RADIOCARBON MEASUREMENTS IN ENVIRONMENTAL STUDIES AT LABEC, FLORENCE

M. FEDI[1], P. ALVAREZ-IGLESIAS[2], L. CAFORIO[1,3], G. CALZOLAI[1,4], V. BERNARDONI[5], M. CHIARI[1], S. NAVA[1], F. TACCETTI[1] AND R. VECCHI[5]

[1]*INFN Section of Florence, Italy*
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[3]*University of Ferrara, Italy*
[4]*University of Florence Italy*
[5]*University of Milano and INFN Milano, Italy*

^{14}C is one of the most widespread radionuclides in nature. Although it is probably best known, especially by the general public, for dating in archaeology, it represents a useful tracer to study our environment, both in the past and nowadays. For instance, carbonaceous particles, which are in many cases the most abundant among aerosols constituents, are believed to play a major role in both the health and the climatic effects of aerosols. In particular, measurement of radiocarbon concentration in particulate matter samples can give information on the contributions of the fossil fuels combustion and of natural sources to the carbonaceous fraction in aerosols. These

measurements are especially effective when separately performed on different carbonaceous fractions, like elemental and organic carbon (EC and OC, respectively). Past climate is also studied thanks to old archives, as marine sediments can be.

In this case, instead of radiocarbon dating the bulk sediment, a reliable method to fix chronological markers is represented by dating foraminifera samples ($CaCO_3$) picked from different layers in the sediment. Both the aforementioned applications are characterized by the fact that samples than can be collected for ^{14}C measurements are typically very small, i.e. few mg or less (before any treatment). Accelerator Mass Spectrometry (AMS) is thus the only technique that can be applied to measure radiocarbon in such samples. Anyway, measurements cannot be so straightforward. In the case of the measurement of radiocarbon concentration in aerosol samples, a preparation line especially dedicated to the extraction of only the carbonaceous fraction of interest is mandatory. Actually, this line should include a combustion oven, from which either total carbon or EC and OC can separately evolve, and a system of traps to purify and collect the CO_2. In the case of foraminifera, special care must be taken in the pre-treatment phase: foraminifera can be contaminated by heterogeneous materials, including organic matter too. Pre-treatment should thus remove all the possible contamination without losing too much mass of the samples.

Here we present an overview of the environmental radiocarbon applications the INFN-LABEC laboratory in Florence is involved in. ^{14}C is measured by AMS, using the dedicated beam line installed at the 3 MV Tandem accelerator. In particular, details about the hardware and the experimental procedures are given.

SESSION III

ENVIRONMENTAL PHYSICS

AGE DETERMINATION IN CRYOCONITES WITH ARTIFICIAL AND NATURAL RADIONUCLIDES

H. LETTNER[1], T. WILFLINGER[1], A. TIEBER[1], P. BOSSEW[2] AND A. HUBMER[1]

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Cryoconites („cold dust", gr.) are airborne deposited sediments on glaciers and ice fields where high levels of man-made and natural radionuclides may be frequently detected. In cryoconites of two temperate alpine glaciers investigated so far, the "Hallstätter Gletscher" and the "Stubacher Sonnblickkees", artificial isotopes of significant activities identified are ^{137}Cs, ^{134}Cs, ^{238}Pu, $^{239+240}$Pu, ^{90}Sr, ^{241}Am, ^{60}Co, ^{125}Sb, ^{154}Eu, and ^{207}Bi, alongside with the natural radionuclides ^{210}Pb, ^{7}Be, and ^{40}K occurring in higher levels. In Central Europe artificial radionuclides in the environment are stemming from two sources, which can be separated according to their isotopic composition and their isotopic ratios. The first source, the Global Fallout of the nuclear weapon test era, culminated in the late 1950ies to the beginning of the 1960ies. The second source was the Chernobyl Fallout in April / May 1986 depositing partly extremely high radionuclide levels in the Eastern Alps of Central Europe. Separation and age allocation of cryoconites can mostly be accomplished with cesium- and plutonium isotopes and their ratios. This method has been developed and successfully applied on cryoconites of the Hallstätter Gletscher [1]. However, the experimental measurement of Puisotopes is rather time consuming, labour-intensive and more or less impossible in very young and very old cryoconites. For these situations another option for age determination is realized with the natural radioisotope ^{210}Pb that is produced continuously by ^{222}Rn decay in the atmosphere and deposited continuously as well. On cryoconites of the Stubacher Sonnblickkees the different methods of age estimation are demonstrated.

[1] Tieber A., "Accumulation of anthropogenic radionuclides in cryoconites on Alpine glaciers", Journal of Environmental Radioactivity 100 (7), 590-598 (2009)

ENVIRONMENTAL RADIOACTIVITY MEASUREMENTS: CHALLENGES AND LESSONS LEARNED FROM THE IAEA ANALYTICAL PROFICIENCY TESTING 2005-2010

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The activity concentration of natural and artificial radionuclides in environment is a critical factor in assessing the potential impact and hazard of possible pollutants. Radioactivity may be present in the environment due to natural processes; intentional (low level) anthropogenic release; or as a consequence of nuclear or radiological incident. The resulting environmental impact should be considered carefully to ensure safety and compliance with environmental regulations. Therefore, a reliable determination of natural and artificial radionuclides in environmental samples is necessary to comply with the radiation protection and environmental regulations.

The International Atomic Energy Agency (IAEA) assists its Member States laboratories to maintain their readiness by coordination activities by developing standardized methods for sample collection and analysis and by conducting interlaboratory comparisons and proficiency tests as a tool for external quality control. The IAEA proficiency tests are designed to monitor and demonstrate the performance and analytical capabilities of the analytical laboratories, and to identify gaps and problem areas where further development is needed.

In this framework, the performance evaluation results of the proficiency tests performed in the frame of the IAEA ALMERA network (Analytical Laboratories for the Measurement of Environmental Radioactivity) and world wide proficiency tests for the determination of radionuclides in various environmental matrices will be presented and discussed. The strong points and the shortcomings of the analytical performance observed in the results of the participants of the IAEA proficiency tests will be pointed out. Lessons learned from the IAEA proficiency tests related to the difficulties in selected analytical procedures will be presented. In addition, analytical methods which needs further improvement and the need for capacity building in specific analytical techniques will also be presented.

ENVIRONMENTAL RADIOACTIVITY MEASUREMENTS WITHIN THE ERMES EXPERIMENT AT THE ULTRA LOW BACKGROUND FACILITY STELLA

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**on behalf of ERMES Collaboration - Gran Sasso National Laboratory, Italy*

ERMES (Environmental Radioactivity Monitoring for Earth Sciences) is an experiment located at the Gran Sasso National Laboratories (LNGS) devoted to environmental radioactivity measurements. Over the past six years many environmental samples have been measured using γ-ray spectroscopy at the LNGS ultra low background counting facility STELLA (SubTErranean Low Level Assay). The experimental set-ups will be described shortly. A summary of the most important measurements within the ERMES activities and their results will be given. Moreover, possible developments and upgrades will be discussed briefly.

RADIOACTIVITY MEASUREMENTS IN VOLCANO-TECTONIC AREA FOR GEODYNAMIC PROCESS STUDY

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In the last ten years we carried out several radioactivity investigations on Mt. Etna in order to characterize radiometrically etnean area with the main purpose to investigate on any correlation between radon concentration and geodynamic events, of volcanic and/or tectonic origin. As known, many studies have shown that radon can be a precursor of geophysical events, most of them were performed either in tectonic or in volcanic area. The peculiarity of our investigation lays on the choice of the etnean region, in which both tectonic and volcanic features are present. Mt. Etna is, in fact, a complex active volcano with four summit craters, more than 300 lateral vents and cones on its flanks and with several fault systems.

In-soil radon gas continuous measurements, carried out from 2001 till 2006 in the NE flank of Mt. Etna, while several volcanic events occurred, shown a possible correlation between radon concentration trend and geodynamic activity, in particular the magma uprising. The survey was performed using different methodologies for both short and long term measurements for reconstructing radon horizontal concentration profiles near active faults and vertical profiles at

different depths in order to determine the diffusivity of radon and its correlation to geogas (CO_2) flux.

Radiometric characterization of the investigated sites was completed with laboratory measurements of concentrations of radionuclides in groundwater samples, by means of scintillation technique, and in rock samples by gamma spectroscopy. With the aim to better define the transport process of radon through fractured media, laboratory measurements are performed on rock samples at different controlled physical conditions (porosity, temperature, pressure, water content) in order to extract radon exhalation rate in simulated volcanic environment. The results will represent a contribution to enlighten on correlation between radon concentration and volcano/tectonic activity.

THE APPLICATION OF GEOTECHNOLOGICAL TOOLS FOR THE CONSTRUCTION OF Cs-137 VULNERABILITY MAPS IN BRAZILIAN SOILS

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The behaviour of radionuclides in soil is governed by several mechanisms that can vary significantly according to the specific reactivity of each element and soil properties. Previous radioecological studies in some Brazilian soils showed that properties such as high acidity, very low organic matter content, low fertility and high Fe-Al oxide content make them more vulnerable to radionuclides contamination than temperate soils. The soil to plant transfer factor (TF) is the parameter that describes the interaction occurring between the soil and plants for a given radionuclide. The existence of various soil classes associated with different agricultural species and regional cultural practices, results in a broad range of transfer values for the same radionuclide. However, it has been experimentally observed that if a soil has specific properties that favor radionuclide transfer, any species growing in this soil will present a high concentration of this contaminant. In this work the objective was to develop a methodological tool to map rural soils, defining their vulnerability to ^{137}Cs contamination. Previous radioecological studies identified that for each category, some soil properties showed to be more relevant than other, so based on pedological analyses for a given class of soil, was theoretically possible to classify the area according to their potential vulnerability and estimate TF. For that we used the software ArcGIS (ESRI) to construct a Geographic Information System basing on 1) Brazilian soil classes; 2) soil to plant transfer factor values for reference species obtained in experiments conducted in Brazilian soils and other extreme case studies reported in the literature 3) soil parameters that interferes on ^{137}Cs behavior in soil such as exchangeable K, cation exchange capacity, pH and organic matter content. It is important to note that a same class of soil can present different levels of vulnerability

depending on soil properties, so the soil class is an important input only to define limit of areas. The vulnerability of soils to ^{137}Cs contamination was defined considering five categories: 1) extremely vulnerable soils, where TF for cereals are expected to be ≥ 1 and remains high with the soil ageing; 2) highly vulnerable, where TF for cereals are expected to be between <1 and ≥0.1; 3) vulnerable soils, where TF for cereals are expected to be between <0.1 and ≥0.05; 4) mildly vulnerable soils, where TF for cereals are expected to be between <0.05 and ≥ 0.01, and 5) invulnerable ageing soils, where TF for cereals are expected to be <0.01 and reduce with the soil ageing. A test map was built using a real area with some Brazilian soils with known physico-chemical properties, but unknown TF and areas representing soils where values reported for ^{137}Cs TF and soil properties were available in the literature originated from experimental essays studies, carried out in nuclear tests areas or Chernobyl accident. Our first approach showed that vulnerability of the studied soil from the real area (Cambisol and Ferralsol) varied from the highly vulnerable and vulnerable, what was very consistent with experimental results obtained in other soil classes from Brazil (Histisol, Ferralsol, Acrisol and Nitisol). This mapping can be an important tool to improve planning emergency actions in rural areas identifying vulnerable areas and suitable remediation.

SESSION IV

GROUNDWATER-SEAWATER INTERACTIONS

RADIONUCLIDE TRACERS OF SUBMARINE GROUNDWATER DISCHARGE ON AN OCEAN ISLAND (GUAM)

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Ocean islands, while a minor fraction of the earth's coastline, are thought to support as much as one-third of the global land to ocean submarine groundwater discharge (SGD). Such estimates are derived from a water balance, which is primarily the residual between two large terms: mean annual precipitation and evapotranspiration. Given the uncertainties associated with this approach and the disproportionate role that islands may play in global SGD, independent and direct estimates are required. This paper will focus on a submarine groundwater discharge method intercomparison on Guam, an island in the western Pacific Mariana Island chain. The island geology is a mix of volcanic and karst; as a result, SGD is dominated by submarine seeps and springs. Radium isotopes and radon were applied as tracers of SGD in Tumon Bay, a large, semi-enclosed lagoon on the northwest coast. Water fluxes derived from the isotopic methods will be compared with a salt balance for the same time period, as well as two historical estimates of SGD: flume capture of large submarine springs and porewater chloride modeling. Reasonable agreement among these five methods suggests that the water balance approach may be suitable for application on a global basis.

THE KINETICS OF THE WATER/AIR PHASE TRANSITION OF RADON AND ITS IMPLICATION ON ON-SITE RADON-IN-WATER DETECTION

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The application of radon as naturally occurring aquatic tracer often necessitates the continuous detection of radon-in-water concentrations. The recording of concentration time series is generally accomplished by stripping of radon from a constant water pump stream into a defined air volume, which is circulated in a closed loop through an attached radon-in-air detector. Assuming air/water distribution equilibrium of radon, the detected radon-in-air concentration can easily be converted into the related radon-in-water value. However, in case of a sudden change of the radon-in-water concentration a distinct delay in re-establishing the air/water distribution equilibrium is observed. The time lag between the concentration change in the water and the related response detected by the radon-in-air monitor is due to the kinetics of the water/air phase

transition of radon and is observed for both, sudden increases and sudden decreases of the radon-in-water concentration.

The response time of a specific detection setup depends on its design and its mode of operation. A parameter of major influence is the water flow rate through the radon stripping unit. Reported data show that high water flow rates substantially improve the response. However, whereas high water flow rates can easily be achieved in the laboratory (employing high capacity pumps), the related options met in the field (e.g. on a boat) are often limited due to the available, in general battery-operated equipment. An alternative option for improving the response time of the detection equipment is the optimization of two other influential parameters: (i) the extent of the water/gas interface and (ii) the volume of circulating air. It is a well-known fact that mass-transfer kinetics and hence the time for establishing a distribution equilibrium between two phases is directly proportional to the available interfacial area. Also the ratio of the phase volumes of sampled phase (i.e. pumped water stream) and receiving phase (i.e. circulating air) has a considerable influence on the response time of the applied detection setup.

In an extended series of laboratory experiments several experimental setups with varying volume/interface ratios have been tested at a constant low water flow rate (2 l/min). The results give clear evidence that the response of the detection setup can, also at low water flow rates, be significantly improved by adjusting the volume/interface ratio. After a short introduction into the theoretical aspects of the kinetics of water/air transition of radon, experimental results will be presented and options for a response time optimized on-site setup for radon-in-water detection will be suggested.

STUDY OF SUBMARINE GROUNDWATER DISCHARGE BY RADIO-TRACER TECHNIQUES AT KALOGRIA BAY, SW PELOPONNISSOS, GREECE

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The Kalogria Bay is located in southwestern Peloponnissos, in the Messinia prefecture. Many sources of submarine groundwater discharges are easily observed around the bay, although the most intensive one is located ~180 m offshore. At this site, groundwater is emanating into the sea through several adjacent submarine openings at 25 m depth. Divers were occupied to collect water samples and to deploy a lander equipped by several sensors. “KATERINA” sensor is an autonomous in-situ underwater gamma-ray NaI(Tl) spectrometer. It was set up submersed accompanied by CT data probes and rotor flow meters to monitor radionuclides (mainly radon progenies ^{214}Pb, ^{214}Bi and ^{40}K) concentration. Long term time-series were acquired, unveiling the

relation between radionuclides' concentration and flux velocity. Radon's progenies average activity revealed proportional to water flow fluctuations while potassium exhibits an inverse proportional variation with flow fluctuation. Additionally, broad range salinity measurements were found to be correlated with radon progenies activities obeying a second order polynomial relationship. Moreover, seasonal laboratory measurements were performed in water samples by a high purity germanium gamma-ray detector, estimating the residence time of groundwater, based on activity ratio concentrations of radium progenies.

NEW DATING METHOD: GROUNDWATER RESIDENCE TIME ESTIMATED FROM HE-4 ACCUMULATED RATE CALIBRATED BY USING COSMOGENIC AND SUBSURFACE PRODUCED CL-36

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Groundwater has contained various noble gas components. Their origins are generally the atmospheric except He and ^{40}Ar. The dissolved He concentration increases with increasing the residence time, because the He dissolved in groundwater has three different sources, i.e. the atmospheric, the radiogenic and the mantle component released from the deep earth. Both radiogenic and mantle are added in groundwater with increasing the residence time. If ^{4}He accumulation rate is constant, the ^{4}He concentration dissolved in groundwater is equivalent for time. Mechanisms of accumulation of ^{4}He are the direct release by the alpha decay in rock matrix, the diffusion from ancient He left in rock, the diffusion from the mantle sources and the transport by advection flow of groundwater. Since groundwater flow is very small in deep strata owing to hydraulic gradient being very small or negligible small, the He accumulation is mainly controlled by other three mechanisms, the direct release from alpha decay, the diffusion from left He in rock and the diffusion of mantle He. The direct release of He can be estimated from the magnitude of alpha decay using concentration of U and Th in rock, and porosity of rock. On the other hand, since other mechanisms are not easily estimate in the field, we practically estimate the He accumulation rate during the half life of ^{36}Cl (3.01×10^{5} years) as the basic time scale.

We estimated the ^{4}He accumulation rate, which included all mechanisms and all He components, calibrated by the cosmogenic ^{36}Cl decay at the Great Artesian Basin (GAB), Australia and the subsurface produced ^{36}Cl growth at the Äspö HRL, Sweden. ^{4}He accumulation rates ranged from 1.85 ± 0.31×10-11 – 15.1 ± 6.3 ×10-11 ccSTP/$cm^3\cdot y^{-1}$ for GAB using cosmgenic ^{36}Cl alone. We confirmed flowing groundwater with the residence time of 0.7-2.2 Ma in GAB. On the other hand, ^{4}He accumulation rates were estimated to be 1.83 ± 0.72×10-8 ccSTP/$cm^3\cdot y^{-1}$ for Äspö using subsurface produced ^{36}Cl alone. We confirmed existing stagnant groundwater with the longest

residence time of 4.5 Ma in Äspö. Consequently, we estimated the very long groundwater residence time over more than 2 Ma, which can not estimate by the dating method of ^{36}Cl alone, using the dissolved ^{4}He concentration even after cosmogenic ^{36}Cl decaying or subsurface produced ^{36}Cl reaching the secular equilibrium.

Science both cosmogenic and subsurface produced ^{36}Cl usually coexist in a natural groundwater system, we can estimate the residence time in combination with two methods verified in GAB and in Äspö, separately. In conclusion, we can deduce the groundwater residence time from the dissolved ^{4}He concentration and the ^{4}He accumulation rate during ^{36}Cl half life, provided that ^{4}He accumulation conditions, groundwater flow conditions and other geo-environmental conditions have not changed for the required geological time scale.

A NEW TECHNOLOGIC DEVELOPMENT FOR REMOTE RADIOLOGICAL MONITORING AND EARLY DETECTION OF ENVIRONMENTAL RISKS IN THE STRAIT OF GIBRALTAR

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Environmental monitoring primarily aims through sampling or by the use of direct detection equipment to quantify the levels of radioactive substances and ionising radiation resulting from human activities and natural sources in the different compartments of the environment. Its objectives are very practical and include the quantification of the environmental sources of ionising radiation and the verification of compliance with regulatory requirements and permit limits for industrial, research and medical activities, as stated by their specific licence.

The continuous and remote environmental monitoring of the sea is a long-time pursuit objective of the international scientific community. It is absolutely essential for an accurate forecast of the state of the sea, for the early detection of environmental risks (accidental spillage of hazardous materials) and for the understanding of some long-term processes as those related with climate change.

REMUS project involves new technological developments that allow real-time and continuous remote monitoring of sea areas using autonomous probes in anchored buoys, powered with solar panels and equipped with low consumption sensors and one onboard PC that communicates via GSM with a central laboratory in land. Sensors incorporate a very sensitive (few Bq m^{-3}) NaI detector for gamma-emitting radionuclides, oceanographic instruments (current meters, CTDs), and chemical sensors (pH, chlorophyll, etc.). This technology allows the remote environmental monitoring of the upper sea (although some additional sensors can be equally deployed in depth)

combining the interest in the early detection of environmental risks (releases of many hazardous materials) and the fundamental research in marine systems, as challenge in the preservation of natural resources and the human health through the knowledge. Thus, the development of predictive models is also one objective of this project. We selected the Gibraltar Strait as an excellent scenario where implement a project based on this new technology. The Strait of Gibraltar is of enormous environmental significance, as it represents the communication pathway between the Mediterranean and the Atlantic seas, and it may be playing a capital role in the global climate change (through the outgoing Mediterranean salty flow). It is also a sensitive place for accidental releases of hazardous materials, because the intensive ship-traffic, including nuclear cargo and nuclear propulsion ships, the complex longitudinal and transversal trade routes, and the particular weather and oceanographic conditions (strong winds and currents). The REMUS project started its implementation through the International Atomic Energy Agency (IAEA) Technical cooperation package and follows for continuation through the Morocco-Belgium and Morocco-Spain Co-operation Programmes. Moroccan partners are: CNESTEN, Marine Royale, Port Tanger MED (TMSA) and Ministry of the Environment.

SESSION V

MARINE RADIOACTIVITY

NUCLEAR ANALYTICAL TECHNIQUES IN MARINE STUDIES AT THE IAEA MARINE ENVIRONMENT LABORATORIES

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The world oceans play a vital role for global climate and the total environment, and thereby also in the subsistence of the world population. Both natural and artificial radionuclides are used as tracers and tools in studies to understand and predict processes in the marine environment. IAEA assists Member States with knowledge transfer and capacity building for marine environmental monitoring and baseline studies.

Examples of applied analytical techniques and cooperative studies conducted in the Marine Environment Laboratories of the IAEA, will be presented. These include:

- Low-level gamma spectrometry measurements in an underground laboratory
- Applying tracer techniques for submarine groundwater discharge, climate and pollution studies in coastal areas
- Using radioactive tracers for studying fluxes, mixing and trans-boundary transport of water masses and pollution
- Radiochemical method developments in marine matrices
- Studies on marine particles and “hot particles” in contaminated areas
- Production of reference materials of marine origin for radionuclides, metals and organic compounds
- Training and capacity building in regional seas areas

The laboratory also understands its role as a promoter for international and interregional collaboration for marine environmental studies.

Pu, Am AND Cs SORPTION BEHAVIOUR IN THE BALTIC SEA

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The anthropogenic radionuclides have been introduced into the marine environment due to the global fallout, discharges from nuclear power plants and the fuel reprocessing and various accidents, e.g. from the Chernobyl NPP. The Baltic Sea is still the most contaminated with ^{137}Cs among shelf seas worldwide. The radioactive contamination of the Baltic Sea was mainly studied in respect of the high ^{137}Cs activity concentrations persisting for a long time in water after the Chernobyl NPP accident. There are a limited number of publications concerning the distribution, speciation and sorption behavior of ^{137}Cs, ^{239,240}Pu and ^{241}Am in the Baltic Sea. However, the investigation of sorption behavior of radionuclides is important for future estimations and from the point of view of their possible application in tracer studies of various environmental processes.

Measurements of ^{137}Cs, ^{239,240}Pu and ^{241}Am activity concentrations in water, suspended particles and bottom sediment samples collected at various sampling stations in the Baltic Sea and in the Curronian Lagoon of the Lithuanian economic zone were carried out using gamma-, alpha- and ICP – MS spectroscopy techniques and beta counting in 1997-2010. Collected samples were well characterized using X-ray, FTIR, NMR, Mössbauer spectroscopy techniques. In addition, in situ and laboratory kinetic sorption experiments with natural sea water and bottom sediments at trace concentrations of Cs, Pu(IV), Pu(V) and Am(III) were carried out for better understanding of processes responsible for redistribution and sink of studied radionuclides in the system. The radionuclide bonding to bottom sediments was studied using sequential extraction and their association with humic acids was determined by the conventional extraction with 0.1mol/L NaOH. Humic acids were characterized by FTIR and NMR spectroscopy techniques. Solvent extraction techniques (using TTA, HDEHP, DBM and PMBP) were employed to characterize the oxidation states of plutonium present in the liquid and solid phases after the sorption experiments. Distribution of Pu and Am among sequential extraction fractions in bottom sediments and their association with humic substances were found to be rather different. Fast reduction of Pu(V) in the system of natural seawater-bottom sediments was observed. A large portion of plutonium in the carbonate fraction was found in the Pu(III) oxidation state. Sorption mechanism of studied radionuclides to bottom sediments will be discussed.

Data obtained from the tracer kinetic sorption experiments with Cs, Pu and Am and bottom sediment fractions were used for finding a suitable kinetic sorption model, kinetic constants and the corresponding equilibrium Kd values. It has been found that the modeled data best conform to the mechanism of ion diffusion through the so-called inert layer on the surface of the sediment particles.

Po-210 AS A TRACER OF ENERGY TRANSFER IN MARINE FOOD CHAINS

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Generally, in marine biota ^{210}Po concentrations are higher in comparison with those in terrestrial organisms. As a consequence, much attention has been paid to polonium-210 (^{210}Po) and its precursor lead-210 (^{210}Pb), two radionuclides belonging to the natural uranium series. These radionuclides give a major contribution to the internal radiation dose received by man mainly through ingestion with seafood. High ^{210}Po concentrations in internal organs of some crustacean, molluscs, and fish motivated research on the potential biological effects originated by high radiation doses that may be experienced in some marine species. Analyses of ^{210}Po and ^{210}Pb were made in a plethora of marine species from plankton to the sperm whale and from the sea shore organisms to those living in abyssal depths. Concentrations of ^{210}Po ranged from very low values, of about 0.5 Bq kg^{-1} (wet wt.) in jellyfish, to very high values of about 3x10^{4} Bq kg^{-1} (wet wt.) in the gut walls of sardines, with the general pattern of ^{210}Po>^{210}Pb. ^{210}Po and ^{210}Pb in marine organisms are primarily absorbed from water and concentrated by phyto- and microplankton. Thereafter, these radionuclides are transferred to plankton consumers (herbivores) and to the upper trophic levels with ingested food, displaying higher yield of ^{210}Po transfer than of ^{210}Pb transfer along marine food chains. Investigation of epipelagic, mesopelagic, bathypelagic and abyssobenthic organisms revealed that ^{210}Po is transferred in marine food webs with transfer coefficients varying between 0.1 and 0.7, and similar to those of the energy transfer (ecotrophic coefficients). Data analysis for marine food chains and experimental results suggest that ^{210}Po transfer traces the protein transfer in the food chains.

THE DISPERSION OF Cs-137 IN A SHALLOW MEDITERRANEAN EMBAYMENT (SARONIKOS GULF – ELEFSIS BAY) IN SEASONAL SCALE, ESTIMATED INVENTORIES AND RESIDENCE TIMES

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The activity concentrations of ^{137}Cs in the water column of Saronikos Gulf and Elefsis Bay (Greece) determined during four cruises between winter 2007 and winter 2009 are evaluated in the present study. The methodology used was based on in-situ filtration of seawater through a GF/A disc

prefilter, in order to remove particulates, followed by two cotton wound cartridge filters impregnated by $Cu_2[Fe(CN)_6]$, for the dissolved ^{137}Cs scavenging. The final products were measured by gamma spectrometry. The activity concentrations of ^{137}Cs ranged between 1.0 ± 0.1 and 6.5 ± 0.1 Bq m^{-3} (average: 2.7 ± 1.0 Bq m^{-3}), depending on sampling depth and season with a tendency to background levels. Regarding the vertical distribution of ^{137}Cs, maximum concentrations were observed in the interface between water and sediment during autumn and winter as a result of thermocline breakdown at the end of winter that caused submerge of surface ^{137}Cs into deeper layers. The inventories of ^{137}Cs varied between 0.052 ± 0.004 and 1.315 ± 0.029 kBq m^{-2} (average: 0.355 ± 0.302 kBq m^{-2}), being in the lowest level comparing to the direct atmospheric deposition after Chernobyl accident. Inventories were found higher in the layer below thermocline (in all seasons except summer), hence, it can be concluded that the artificial ^{137}Cs has been transferred below thermocline in Saronikos Gulf (surface deposition has been found negligible). Finally, the mean surface residence time of ^{137}Cs in Saronikos Gulf was estimated to be 15 ± 4 y, whereas the effective half-life of ^{137}Cs in the study area 6.4 y.

SESSION VI

NEW ANALYTICAL TECHNOLOGIES

ICP-MS FOR LOW-LEVEL RADIONUCLIDE ANALYSIS

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With the development of inductively coupled plasma mass spectrometry (ICP-MS) analytical techniques, it is becoming an attractive analytical technique and common used analytical technique for the determination of long-lived radionuclides, especially at low level. Comparing with the conventional radiometric analytical techniques, its major advantage is rapid analytical capacity, normally a few minutes per sample comparing with hours to weeks for radiometric methods. In addition, the separation of interference radionuclides is also less required, consequentially a shorter chemical separation procedure and shorter analytical time is needed. Therefore it is very suitable for the emergency analysis and the analysis of large number of samples in a short time. For radionuclides with very long half-lives, such as ^{99}Tc, ^{237}Np, ^{235}U, ^{238}U, and ^{232}Th, ICP-Ms is also more sensitive than radiometric methods. However, ICP-MS is only an alternative method for the analysis of radionuclides, radiometric methods are still the best methods for the determination of short-lived radionuclides, especially those with half-life lower than 100 years. The major disadvantage of ICP-MS for the determination of radionuclides is the isobaric interferences and abundance sensitivity, especially for those radionuclides with isobaric interferences from high abundant stable or long-lived isotopes of elements, such as the measurement of ^{238}Pu and ^{99}Tc. Therefore ICP-MS cannot be considered as a replacement for radiometric measurements, but merely an alternative and complementary technique. This work will presents the application of ICP-MS in the determination of some low level radionuclides, and an overview of the advantages and disadvantages of ICP-MS comparing with the corresponding radiometric techniques for common interested long-live radionuclides.

SNIFFER: AN AERIAL PLATFORM FOR REAL TIME MEASUREMENTS OF CONTAMINATION IN THE PLUME PHASE OF A NUCLEAR EMERGENCY

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When a nuclear or radiological accident result in a release of a radioactive plume, AGS (Aerial Gamma Spectrometry) systems used in many countries, equipped with passive detectors, can help in giving quantitative assessment on the radiological situation (land surface contamination level) only when the air contamination due to the passage of the travelling plume has become negligible. To overcome this limitation, the Italian Institute of Health has developed and implemented a multi

purpose air sampling system based on a fixed wing aircraft, for time-effective, large areas radiological surveillance (to face radiological emergency and to support homeland security). A fixed wing aircraft (Sky Arrow 650) with the front part of the fuselage properly adapted to house the detection equipment has been equipped with a compact air sampling line where the isokinetic sampling is dynamically maintained. Aerosol is collected on a Teflon filter positioned along the line and hosted on a rotating 4-filters disk. A complex of detectors allows radionuclide identification in the collected aerosol samples. A correlated analysis of these two detectors data allows a quantitative measurement of air as well as ground surface concentration of gamma emitting radioisotopes. Environmental sensors and a GPS receiver support the characterization of the sampling conditions and the temporal and geographical location of the acquired data. Acquisition and control system based on compact electronics and real time software that operate the sampling line actuators, guarantee the dynamical isokinetic condition, and acquire the detectors and sensor data. The system is also equipped with other sampling lines to provide information on concentrations of other chemical pollutants. Operative flights have been carried out in the last years, performances and results will be presented.

QUANTIFICATION OF U-238 IN ENVIRONMENTAL SAMPLES USING GAMMA-RAY SPECTROMETRY

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A large number of environmental samples are routinely measured using gamma-ray spectrometry. A great asset with gamma-ray spectrometry is its possibility to generate quantitative data for many radionuclides in one analysis. Although other techniques can be considered more suitable for analysing uranium-238 in environmental samples, gamma-ray spectrometry is often used for this task. One cannot always assume that the complete decay chain is in equilibrium so ^{234}Th is mainly used for determining the ^{238}U activity. The low-energy gamma-rays at 63 keV and 92.5 keV are very difficult to quantify due to high attenuation and interferences. This paper compares techniques to make robust quantification of ^{238}U via ^{234}Th using gamma-ray spectrometry.

REDUCTION OF COSMIC RAY COMPONENTS ON GE DETECTOR UTILIZING THIN PLASTIC SCINTILLATORS AND WAVELENGTH SHIFTING FIBERS FOR ANTICOINCIDENCE

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The contribution of cosmic ray components on background of Ge detector is reduced by means of an active anti-coincidence detector system. In order to insert into lead shield in Ogoya Underground Laboratory [1] and to cover 2π geometry of Ge detector, five thin plastic scintillators (PSs) (180 mm x 180 mm, and 3 mm in thickness; ELJEN TECHNOLOGY; EJ-200) connected with five wavelength shifting fibers (1 mm in diameter; BICRON BCF-91A) that was coupled to one small PMT (1/2" in diameter; HAMAMATSU H3165-10) through five clear fibers and optical couplers has been developed. In order to detect only cosmic rays components, therefore to make a counting rate low, this PSs system was inserted into inside of conventional passive shield of Ge detector. A sum circuit is unnecessary in this system. All events were recorded in list mode. Relative efficiency of PSs, time spectra, time dependence of coincidence events, multiple coincidence events, and single, coincidence and anticoincidence spectra were tested. A typical counting rate of PSs, Ge, and coincidence events were roughly 1000, 130 and 50 min^{-1}, respectively. Multiple PSs events a Ge event have sometimes been detected. This thin PSs system has adequate thickness to detect cosmic ray components. It is expected to reduce more than 50% of cosmic ray induced background components of Ge detector. This system is effective not only in an underground laboratory but aboveground laboratory.

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STUDIES OF INDUSTRIAL EMISSIONS BY ACCELERATOR-BASED TECHNIQUES AT CEDAD

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CEDAD (Centre for Dating and Diagnostics) is a multidisciplinary research centre of the University of Salento involved in applied and fundamental research activities in different research fields such

as AMS (Accelerator Mass Spectrometry) radiocarbon dating, cultural heritage diagnostics by mean of non-destructive IBA (Ion Beam Analysis) techniques and environmental monitoring. The centre is based on a 3 MV Tandetron accelerator equipped with experimental beam lines for AMS ^{14}C dating, PIXE (Particle Induced X-Ray Emission)-PIGE (particle Induced Gamma Ray Emission) in external beam mode, nuclear microprobe and high energy ion implantation.

In the field of environmental monitoring different research activities are in progress as related to the use of AMS for monitoring the anthropogenic carbon dioxide emissions into the atmosphere and for the quantification of the biogenic fraction in carbon based products as plastics, resins, bio-fuels and in industrial atmospheric emission such as flue gas from WTE (Waste to Energy Plants). In fact as the result of the large isotopic difference existing in terms of ^{14}C concentration between fossil-derived and bio-based products, the radiocarbon method is becoming more and more important in this field.

Recent results in the analysis of the dispersion of CO_2 emissions from coal-fired power plants, in the analysis of the biogenic content if SRF (Solid Recovered Fuel) burned in WTE (Waste to Energy Plants) and in the quantification of the biogenic-derived fractions in industrial plastic materials will be presented in this work.

SESSION VII

ISOTOPE OCEANOGRAPHY

DISTRIBUTION OF Cs-137 IN THE SOUTH PACIFIC AND INDIAN OCEAN WATERS: RESULTS OF THE SHOTS PROJECT

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The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) conducted in 2003-2004 Blue Earth Global Expedition (BEAGLE2003), visiting the South Pacific (winter), the South Atlantic (late spring) and the South Indian (summer) Oceans. We provide here a first view of transects of current ^{137}Cs concentrations along 30 S in the Pacific and along 20 S in the Indian Ocean. The present concentrations of ^{137}Cs in the South Pacific and Indian Ocean surface waters were the same order of magnitude as that in North Pacific surface waters, although the atmospheric input in the South Oceans was less than one-third of the North Pacific. ^{137}Cs water column inventories in the western central South Pacific, calculated from the ^{137}Cs vertical profiles, were about 1000 Bq m^{-2}, which is markedly higher than cumulative deposition observed in the east-central Australia. We propose from these findings a hypothesis that significant amounts of the North Pacific ^{137}Cs have been transported to the Indian Ocean via Indonesian Sea and the central South Pacific (Tasman Sea) across the eastern Equatorial Pacific at the time scale of several decades. These findings suggest that the south Pacific central gyre, as well as the south Indian subtropical gyre are major reservoirs of global-scale ocean contaminants. ^{137}Cs has been found to be a powerful tool to solve inter-ocean transport of water masses and pollutants at several decades.

U-236 IN OCEAN WATER SAMPLES

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Several studies have shown that ^{236}U is a valuable tracer to identify the anthropogenic origin of material with elevated concentrations of artificial radionuclides [1, 2 and references therein] However, the potential of naturally produced ^{236}U as a tracer for geologic processes is largely unexplored [3]. This is mainly due to the fact that precise mass spectrometric measurements of

^{236}U at femtogram (10^{-12}g, fg) levels are challenging due to the presence of background from the abundant U-isotopes ^{235}U and ^{238}U. Up to date, accelerator mass spectrometry (AMS) is probably the only technique that is able to determine natural $^{236}U/^{238}U$ levels below 10^{-10} with sufficient efficiency [4]. Recently, ^{236}U measurements have been established on our compact (0.6 MV) AMS system Tandy at background levels in the range of 10^{-12} [5]. The low level of background together with a good over all efficiency of both sample preparation and AMS measurement now enables us to precisely determine small amounts (some fg) of ^{236}U in environmental samples.

In this study we focus on the preparation and the measurement of Ocean water samples. We present an easy to use method to extract small amounts of ^{236}U from 10-100 liter ocean water samples. In contrast to previous AMS measurements of ^{236}U we use a certified ^{233}U reference material (IRMM058) as a spike to trace the yield of the chemical preparation procedure. This enables us to determine both the ratio of $^{236}U/^{238}U$ in the sample material and the concentration of ^{236}U during only one AMS-measurement.

First results from water samples collected in the North Sea in 2009 clearly indicate the influence of anthropogenic ^{236}U from discharge waters of the nuclear reprocessing plants. Highest concentrations of 167 x 10^6 at/l corresponding to a $^{236}U/^{238}U$ ratio of 2.2 x 10^{-8} were found in the English Channel in the vicinity of La Hague. To estimate the amount of natural ^{236}U in the Atlantic Ocean a depth profile was sampled in the South Atlantic Ocean. The samples are currently processed and the results of the measurements will be presented at the conference.

Since our data represent the first ^{236}U measurements from ocean water samples our work significantly contributes to map the distribution of both natural and anthropogenic ^{236}U in the Ocean and thus to explore the potential of ^{236}U as a new oceanic tracer.

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[2] Sakaguchi, A., et al. (2009), First results on 236U levels in global fallout, Science of The Total Environment, 407(14), 4238-4242

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ANTHROPOGENIC RADIONUCLIDES IN THE MEDITERRANEAN SEA: SPACE AND TIME-DISTRIBUTION, MASS-BALANCE AND FUTURE TRENDS

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The main sources of anthropogenic radioactivity to the Mediterranean Sea are fallout from atmospheric nuclear weapon testing and from the Chernobyl accident in 1986, while the releases from the nuclear industry are small. Consequently, present radionuclides levels in the marine environment are of no concern from the radiological point of view. However, the Mediterranean Sea is an ideal environment to show how both coastal and open-sea processes act to re-distribute radionuclides in the different compartments of the marine environment. In fact, the Mediterranean Sea is considered a miniature ocean, where all the processes characterizing the global ocean take place on smaller space and time scales. For these reasons, in the last decades it has largely been used as a "laboratory basin" for process studies. In this framework, anthropogenic and natural radionuclides were often measured to be used as tracers of water mass dynamics, transit and renewal times, particle dynamics, sediment accumulation, etc.

In this work we first briefly describe the physical and biogeochemical characteristics of the Mediterranean Sea. After reviewing and quantifying the sources of radioactivity, we mainly focus on two anthropogenic radionuclides: (i) ^{137}Cs, conservative in the open sea, the most abundant anthropogenic radionuclide and, among these, the main contributor to dose to the population, and (ii) the very long lived ^{239,240}Pu, non conservative, the most abundant among transuranics. We describe their distribution and time trend in seawater, sediments and biota, define their budgets in the basin, quantify the exchanges at the Gibraltar and Turkish Straits and indicate future trends. We then give some examples on how the distributions have been used to trace oceanographic processes, contributing to better understand the functioning of the whole Mediterranean marine ecosystem. Finally, we highlight knowledge gaps and identify topics for future research, mainly related to the application of nuclear techniques to the study of oceanographic processes.

INVESTIGATION OF CIRCULATION OF WATER MASSES IN THE SOUTHERN INDIAN OCEAN USING RADIONUCLIDE TRACERS

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Fifty years after the main injection of anthropogenic radionuclides (^{3}H, ^{14}C and ^{137}Cs) from nuclear weapons tests on the ocean surface their concentrations in seawater of the southern Indian Ocean have been surprisingly high, comparable with levels observed in the North Pacific and North Indian Oceans. The isotopic tracers reveal the evidence of the most intense surface gradients and presence of several water masses, which makes the southern Indian Ocean one of the most dynamic places of the World Ocean. The Indian Ocean Subtropical Gyre acts as a radionuclide reservoir, maintaining their high concentrations on a time scale of several decades.

ACTIVITY SIZE DISTRIBUTION OF BE-7 IN ASSOCIATION WITH TRACE METALS AND THEIR DEPOSITION ON THE SEA

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The activity size distributions of the natural radionuclide tracer ^{7}Be and associated trace metals in different inhalable fractions (<0.39 μm, 0.391-0.69 μm , 0.69-1.3 μm, 1.3-2.1 μm, 2.1-4.2 μm, 4.2-10.2 μm and >10.2 μm) were determined in a typical traffic-affected urban site in the center of the city of Thessaloniki, Greece, over a seven month period (June'09-January'10). The activity median aerodynamic diameter (AMAD) ranged from 0.58 to 1.22μm (avg 0.80μm). The AMAD values are anticorrelated to ^{7}Be activities, while they are correlated with RH% with high confidence ($R=0.92$, $p<0.00813$). The most probable explanation for this positive correlation between AMAD values and RH% is that the condensation during high relative humidity conditions becomes more intense, resulting in increased particle sizes of atmospheric aerosols. The composition of the associated particles is basically Ca, Si and S. Among the heavy metals determined, Fe is the most abundant, followed by Cu. Minor amounts of Pb, Cr, Ni are presented in coarse size ranges. The amount of Fe increased with decreasing particle size, displaying positive correlation with AMAD of ^{7}Be in case of strong wind from NW direction and indicating the transport of polluted air from the industrial area

of the city of Thessaloniki. Sea salt aerosol particles were defined in only small size range, lower than 0.39 μm and during a sampling day with clear atmosphere with wind of 3.2-4.8 km h^{-1}. Since the city of Thessaloniki is located near the sea the appearance of sea salt aerosols is very well explained. Furthermore our field measurements at coastal location give us the opportunity to estimate ^{7}Be deposition on the sea. Since the ^{7}Be aerosol particles are mainly below 1μm, scavenging by precipitation is the main process depositing ^{7}Be on the sea. Acting as an excellent tracer, ^{7}Be, could be used for determination of the deposition of the associated trace elements, since they are expected to be deposited on the sea at similar rate by wet and dry deposition processes as the ^{7}Be.

SESSION VIII

RADIOECOLOGY

RADIOLOGICAL CONDITIONS IN SOUTH IRAQ WHERE DU MUNITIONS WERE USED

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During the conflict in Iraq in 2003, depleted uranium (DU) munitions were employed by the Coalition Forces. As a result, residues of DU contaminated both localized areas of land and vehicles. The possible health effects of such residues on the Iraqi population living in the vicinity of the affected areas raised concerns in Iraq as well as in other parts of the world. In 2004 UNEP, after receiving a formal request from the Iraqi Minister of Environment for a comprehensive field assessment to investigate the use of DU and its residual impacts, trained and equipped national experts from the Radiation Protection Centre (RPC) of the Iraqi Ministry of Environment to undertake a sampling campaign for DU in Iraq. RPC staff collected environmental samples at selected sites in southern Iraq during sampling campaigns conducted in 2006-2007. A total of 520 samples of soil, water, vegetation and smear samples were taken. The samples were collected at four locations in southern Iraq, namely, As Samawah, AnNasiriyah, Al Basrah and Az Zubayr. The samples were then shipped from Iraq to UNEP in Geneva, Switzerland, and analysed by the Spiez Laboratory in Switzerland using state of the art ICP-MS.

The IAEA subsequently undertook a radiological assessment of the results obtained through the sampling campaign. For this purpose, the IAEA convened a team of experts who were involved in past similar radiological studies in different post-conflict situations involving DU. The team was led by P.R. Danesi, an external consultant and former Director (1986-2002) of the IAEA Laboratories. In the radiation dose assessment, the following exposure pathways were considered:

- Inhalation of DU contaminated soil re-suspended by the action of wind or human activities;
- Inhalation of re-suspended DU dust inside military vehicles hit by DU munitions;
- Ingestion of DU contaminated soil;
- Ingestion of DU contaminated vegetables and drinking water;
- Direct contact with DU penetrators or DU fragments;
- Ingestion of DU contaminated dust from flat surfaces (metal, concrete, walls);
- Inhalation and ingestion of DU during operations at scrap metal facilities involving military vehicles hit by DU munitions.

On the basis of assumptions on the habits of local residents, which were corroborated by the experts from the Iraqi RPC, and the results of measurements of environmental samples, the estimation of the radiological risk from DU was performed in a conservative way. Assumptions concerning human habits and exposure scenarios were made such that radiation doses at the upper end of the possible range would result.

The study concluded that the radiation doses from DU do not pose a radiological hazard to the population at the four studied locations in southern Iraq. The estimated annual committed effective radiation doses that could arise from exposure to DU residues are low, always less than 100 µSv/a and only to a few, if any, individuals, and therefore of little radiological concern. The

estimated radiation doses are less than those received on average by individuals from natural sources of radiation in the environment (worldwide average 2.4 mSv/a), below internationally recommended dose limits for members of the public (1 mSv/a) and below the action level of 10 mSv/a set out in the IAEA Safety Standard on Remediation of Areas Contaminated by Past Activities and Accidents to establish whether remedial actions are necessary.

The doses that could be accumulated by individuals who enter abandoned vehicles which have been hit by DU ammunition may be higher than those from DU in the environment due to the inhalation of residual dust containing DU inside the vehicles. The study recognized that such vehicles may present an inhalation hazard and members of the public should be prevented from entering them.

In the absence of special facilities, the study also concluded that it is not advisable that metal from vehicles hit by DU munitions be used as scrap metal and direct disposal as low level radioactive waste (LLRW) (without any decontamination) should be preferred from a radio¬logical perspective since it is associated with fewer potential exposure pathways.

Although very few DU penetrators or DU or penetrator fragments were identified during the sampling campaign, it cannot be excluded that they might be found and collected by members of the public in areas where DU munitions were used. Although the radiation dose would become significant only if the person exposed were to be in direct contact with DU munitions or fragments for a considerable period of time, nevertheless, the handling of DU penetrators or fragments should be kept to a minimum, and protective gloves should be worn when DU munitions are being handled. DU fragments and penetrators should be considered and managed as LLRW.

The conclusions of this study were similar to those reached in international studies of other situations where DU munitions were employed (Kuwait and the Balkans) and support the belief that the radiological impact of the residues from the firing of DU munitions is also likely to be low in other parts of Iraq.

ENVIRONMENTAL CHALLENGES OF HIGH ENERGY/INTENSITY HADRON ACCELERATORS

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The recent developments in accelerator technology allowed for such energy and intensity of hadron beams (e.g. the CERN Neutrinos to Gran Sasso, CNGS, facility or the Large Hadron Collider, LHC) so that the environmental aspects of these facilities are no more trivial. The talk makes an overview of the main radiological environmental aspects of high energy/intensity hadron

accelerators and the way they can be treated so that their impacts are minimized. The main aspects are emission of stray radiation, comprising high-energy muons and neutrons, as well as releases of radioactive substances. The latter aspect includes short-lived radioactive gases, which usually dominate the dose to members of the public but also tritium, which is not radiologically important but which is easy to detect and whose presence is often misused by environmental pressure organizations.

EVALUATION OF ENVIRONMENTAL SENSITIVITY OF THE MARINE REGIONS

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The knowledge about environmental sensitivity of the marine regions to radionuclide release can be used for the development of response strategies and improvement of design-maker systems.

The present results are based on the consequences analysis after potential Russian submarine accident involving a modern vessel. The geographical location of the accident, with subsequent release, has been set to the marine region outside the Russian-Norwegian border areas in the Barents Sea close to the operating naval bases in Northwest Russia.

More than 60 radionuclides were included in the investigation. The radioecological consequences are based on modeling of potential releases of radionuclides, radionuclide transport and uptake in the marine environment. Modeling work has been done using a revised compartment model developed at the Norwegian Radiation Protection Authority. The model includes the processes of advection of radioactivity between compartments, sedimentation, diffusion of radioactivity through pore water in sediments, resuspension, particle mixing including mixing due to bioturbation and a burial process of radioactivity in deep sediment layers. Radioactive decay is calculated for all compartments. The contamination of marine organisms is further calculated from the radionuclide concentrations in filtered seawater. Doses to marine organisms are calculated on the basis of radionuclide concentrations in seawater, sediments and biota. Doses to man are calculated on the basis of seafood consumption.

The sensitivity analysis is based on the comparison of the results of simulations with the recommendations criteria for protection of the human population and the environment.

The results show that for the present evaluation of a potential accident, the marine organisms, living in sea sediment near the accident location, are the most sensitive part of the environment. These organisms have doses, which are significantly higher than the screening dose rate during the lifespan for many generations.

Additionally, results of calculations indicated that concentrations of radionuclides for some marine organisms during initial time of release near the accident location exceeded recommended guideline levels.

RADIOECOLOGY STUDIES IN THE VICINITY OF CLOSED URANIUM MINE

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Uranium mine at Ţirovski vrh, Slovenia, which operated from 1985 to 1990, processed about 600,000 tons of uranium ore. The uranium mill tailings (UMT) were deposited onto the Boršt waste pile lying close to the mine, in the subalpine region with relatively high rainfall and within a relatively densely populated area.

The mining influential area has been under continuous radiological monitoring aimed at assessing additional radiation doses due to mining and milling activities since starting industrial excavations in 1982. However, more detailed radioecology studies were initiated some five years ago. They are focused on assessing mobility and bioavailability of radionuclides present in the tailings pile.

The mobility of ^{238}U, ^{234}U, ^{230}Th and ^{226}Ra was studied by applying Shultz modified Tessier sequential extraction procedure. Samples from six different locations at the repository and in the nearby soils were investigated. The results revealed that the highest activity concentrations were on the bottom of the waste pile. In the non-contaminated locations, about 80% of the radionuclides were in the residual extraction fraction. The uranium isotopes were found to be the most mobile from the UMT, whilst the mobility of ^{226}Ra and ^{230}Th appeared to be suppressed by high sulphate concentrations.

When comparing the revised BCR and the modified Tessier sequential extraction protocols it was found that the protocols are not comparable as the data obtained are protocol- and element-dependent. However, general conclusions about potential source of the particular radionuclide that could be drawn from the study are mostly similar for both protocols.

Uptake of particular radionuclides by the plants grown in the vicinity of the former mine were also investigated. In particular, a common reed grown in soils contaminated with the seepage waters from the tailings was studied. The plants contained elevated levels of ^{238}U, ^{226}Ra and ^{210}Pb compared to the plants from control site. Activity concentrations of the three radionuclides were about five times higher in leaves than in stems.

Activity concentrations of natural radionuclides in milk collected from the area of Ţirovski vrh were comparable to a reference location, except of uranium where the content was higher. The combined annual effective dose for adults consuming milk from the Ţirovski vrh area is 13.0 ± 1.7 µSv/year.

SESSION IX

RADIOECOLOGY

UP-TO-DATE CONTENT OF LONG-LIVED ARTIFICIAL RADIONUCLIDES IN THE TOM AND OB RIVERS IN THE AREA INFLUENCED BY DISCHARGES FROM SIBERIAN CHEMICAL COMBINE

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The Siberian Chemical Combine (SCC) is located in Seversk (formerly known as Tomsk-7) in the Tomsk Region of the Russian Federation. Being mainly intended for production of weapon-grade plutonium and high enriched uranium, the SCC was put into operation in 1953. Main contribution into radionuclide content in SCC process water discharged into the Tom River was given by the single pass reactors previously removed from service (the last SCC reactor was shutdown on June 5, 2008). At the present time, there is lack of data on contemporary influence of SCC radioactive discharges on contamination of the Tom and Ob rivers by long-lived radionuclides. In the course of limited-scope monitoring conducted by the Roshydromet near the SCC (Chernilshikovskaya arm of the Tom river) during SCC reactor operation, the content of only a few (mainly short-lived) gamma-emitters in water was determined. The role of long-lived radionuclides becomes more important due to shutdown of all SCC reactors. Another important factor determining the need for being aware of current radiation situation on the Tom and Ob rivers downstream of the SCC consists in plans for construction of the nuclear power plant (Seversk NPP) in the SCC area. Influence of discharges and releases from the Seversk NPP on contamination of water environment compartments will be monitored in conditions of radioactive contamination due to previous SCC discharges, and awareness of the initial radioactive situation is essential.

The report presents and discusses the data on content of ^{90}Sr, ^{137}Cs, ^{239,240}Pu and other artificial radionuclides in water, bottom sediments and flood plain soils of Tom and Ob rivers along the route of SCC radioactive discharge transport, from Tomsk to the confluence of the rivers. The data were obtained in 2008-2009 within International Science and Technology Center (ISTC) Project No. 3547 "Analysis of Radionuclides Transport and Assessment of Radiation Risk for the Population and Environment in the Basin of the Irtysh-Ob' River System". The results of the observations carried out after shutdown of the last SCC single pass reactor indicate no radiative significant consequences of SCC activities for the studied water environment compartments. Contemporary activity concentrations of long-lived artificial radionuclides, ^{137}Cs, ^{90}Sr, ^{239,240}Pu and tritium, in river water are below the intervention levels established by current regulations of the Russian Federation for these radionuclides. The results of tritium analysis in water from the Tom and Samuska rivers demonstrate no inflow of contaminated formation water to surface water from the sites where liquid radioactive wastes of the SCC are injected below the surface. However, the density of flood plain soil contamination by long-lived ^{137}Cs in the area influenced by SCC liquid discharges is higher than regional technogenic background. There are local flood plain areas contaminated not only by ^{137}Cs, but also other gamma-emitters, such as ^{152}Eu and ^{60}Co.

SEMIPALATINSK NUCLEAR TEST SITE. CURRENT STATE AND PROSPECTS

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Since the shutdown of the test site, Kazakhstani scientists in cooperation with international scientific community have been gaining extensive information on the relative current radiological situation at STS and its vicinity. There have been revealed all significant areas of radioactive contamination, major pathways and mechanisms for current and potential migration of radioactive substances. The whole set of obtained data makes us confident to assume that STS does not adversely impact on the population living in the surrounding areas, except the people living in the zone of the Shagan River.

However, the radioecological situation is not stable; there were found migration processes of radioactive substances, which cause the need for regular monitoring of radiation situation at the test site and further research. It is planned to conduct additional research and practical actions to improve the radiation situation, the following include areas in the priority:

- additional integrated research of the "conditionally clean" territory for the purpose of further transfers of lands into the economy (for a large part of the STS beyond the experimental sites the conducted detail research is insufficient to make a decision on the transfer of the land);
- study of the underground migration of radioactive contamination beyond the test grounds (now there has been found evidence about migration of some radioactive elements (tritium) to tens of kilometres from testing venues);
- completion of the inventory of radioactively contaminated sites with development of projects for their remediation or conservation;
- identifying sites where there may be catastrophic phenomena: gas emissions, collapses, etc. (now we've identified the phenomenon of uncontrolled underground gasification of coal in some parts of the test site);
- develop and implement activities for the physical restriction of access to the zones of strict control and monitoring of economic activities at the STS;
- develop, organize and implementation of regular monitoring of radiation environment on radiation-hazardous objects of STS and areas/objects in the zone of their influence.

National Nuclear Centre of Kazakhstan (NNC) in recent years has been carrying out systematic studies of conventionally clean areas of STS, which are promising in terms of their future use in the economy. At present according to research results of 3000 sq. km of conventionally called STS "northern" territories 2,997 sq. km is recommended to transfer, in the current 2010 we'll complete the study of "western" part of the STS with area of 560 sq. km, and we've obtained preliminary results on 850 sq. km of "southern" part of STS. NNC plans to radically solve the problem of the former test site by 2020.

DISTRIBUTION OF PLUTONIUM AND AMERICIUM IN THE SOILS FROM KOREA

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Plutonium isotopes and ^{241}Am were studied in soil from Korea collected from 2006 to 2008. The aims of this study are to provide information on the distribution and origin of Pu isotopes and ^{241}Am in the soil from the Korean Peninsula. ^{239,240}Pu concentrations in surface soil varied from 0.64 ± 0.04 to 5.02 ± 0.40 Bq kg^{-1}. ^{241}Am concentrations in surface soil showed values from 0.22 ± 0.05 to 2.00 ± 0.08 Bq kg^{-1}.

The ^{239,240}Pu and ^{241}Am of vertical profiles in soil sampled from Nari basin in Ulleung Island in the East Sea/Sea of Japan and Seongsan Ilchulbong Peak, Jeju Island showed higher concentration at the surface layer with a range of 3.0 ± 0.3 to 14.0 ± 1.2 Bq kg^{-1} for ^{239,240}Pu and 0.54 ± 0.04 to 0.56 ± 0.05 Bq kg^{-1} for ^{241}Am, respectively and then gradually decreased. On the other hand, the ^{239,240}Pu and ^{241}Am concentrations with depth in the soils collected from Bukhan Mountain National Park in Seoul showed a subsurface maximum with a range of 1.7 ± 0.1 for Pu and 0.51 ± 0.11 Bq kg^{-1} for ^{241}Am, respectively.

The activity ratios of ^{241}Am/^{239,240}Pu in soils were 0.40 to 0.50 and these values were similar to the global fallout ratio (0.40), which suggests that the source of these radionuclides in the soil in the Korean Peninsula is global fallout. The ^{239,240}Pu inventories in the soil column in Korea were from 75 to 185 Bq m^{-2} and the ^{241}Am inventories were 30 to 69 Bq m^{-2}, respectively.

RADIOECOLOGICAL IMPACTS OF AGRICULTURAL ACTIVITIES ON SANDY SOIL IN ARID ENVIRONMENT

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Soil salinity is a widespread environmental problem, particularly in arid and semi-arid regions of the world. Surface soil samples were collected from 14 locations "arid environment" at the central region of Saudi Arabia. Two samples from each location, one from cultivated land and the second

from uncultivated land, of the same origin were collected from each location. This work aims at investigating the different of soil properties upon dry-land uses and its effects on naturally occurring radionuclides concentration and distribution. The specific activity, in Bq/kg, of ^{226}Ra (^{238}U series), ^{228}Ra (^{232}Th series), and ^{40}K were measured using calibrated gamma-ray spectrometer. The soil physical and chemical properties [e.g. pH, EC, particle size distribution (clay, silt and sand percentages), $CaCO_3$ %, soluble cations (Ca, Mg, Na and K) and soluble anions (CO_3, HCO_3, Cl and SO_4)] were determined. The radium equivalent activity, in Bq/kg, and absorbed dose rate one meter above the ground, in nGy/y, were calculated. Generally, due to the sandy nature of the soil and the effects of adsorption-filtration processes on the behavior and the distribution pattern of natural radioactivity concentrations in arid environment, there is no noticeable change in soil properties due to agricultural activities or strong correlations between soil properties and specific activities. Therefore, the environmental impacts of different man-made activities on underground resources should be carefully considered due to the possible filtration behavior of different pollutants in dry-land environment.

RADIOLOGICAL IMPACT OF GULF WARS ON AGRICULTURAL AREAS IN KUWAIT

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The three successive Gulf Wars in the past 30 years and especially the use of depleted uranium in the last two wars have caused environmental concerns in the State of Kuwait. The primary health hazard arises from possibility of radioactive contamination of agricultural farms due to remnants of depleted uranium. Two main farming areas of Al-Abdaly (north of Kuwait near the Iraqi border) and Al-Wafra (south of Kuwait) produce vegetables for local consumption in Kuwait. In and around these farms there exist some areas where grass and pasture are grown as fodder for animals which provide local milk and meat to the markets. These produce are important for some of the Kuwaiti population's daily diet.

In order to assess the radiological impact of the Gulf Wars on the agricultural produce in Kuwait, we have carried out investigations of soil and plants from the agricultural farms for radioactivity concentrations of various radioisotopes. As part of our extensive study, high-resolution gamma-spectrometry measurements have been performed to evaluate the activity concentration of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs in the samples. We will report on the results of our investigations on activity concentrations of radionuclides in plants, vegetables, soil and grass. Transfer factors from soil to plants will be presented. The total effective dose equivalent for ingestion of local foodstuff by adults and children will be discussed. Results for outdoor extended dose rate, annual equivalent dose and hazard index will also be presented.

COMPARATIVE ANALYSIS OF DOSES TO AQUATIC BIOTA IN WATER BODIES IMPACTED BY RADIOACTIVE CONTAMINATION

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Comparative analysis of doses to the reference species of freshwater biota was performed for the following water bodies: Chernobyl NPPs cooling pond, Lakes Uruskul and Berdenish located in the Eastern Urals Radioactive Trace, Techa River, Yenisei River. It was concluded that the doses to biota were considerably different in the acute and chronic periods of radioactive contamination. It was shown that the radioecological consequences of radionuclides releases to the water bodies depends on the size of aquatic system. The most vulnerable part of all considered aquatic ecosystems was benthic trophic chain. According to the model results, mollusks obtained the highest doses among all reference species both in acute and chronic periods of radioactive contamination of water bodies. During the acute period of contamination aquatic plants obtained high dose rates, because they adsorbed some short-lived radionuclides (^{144}Ce, ^{95}Zr, ^{106}Ru) on their surface.

A numerical scale on the “dose rate – effects” relationships for fish was formulated on a basis of analysis of the EPIC database. Threshold dose rates above which radiation effects can be expected in fish were evaluated to be the following: 1 mGy d^{-1} for appearance of first negative changes in fish blood, and early signs of decrease in immune system; at lower dose loads the organisms seemingly can adapt for radiation with gradual restoration of health parameters; 5 mGy d^{-1} for appearance negative effects on reproduction system; 10 mGy d^{-1} for effects on life shortening; 20 mGy mGy d^{-1} increase of mortality and decrease of fish population.

The results of dose assessment to biota were compared with the scale “dose rate – effects” and the literature data on the radiobiological effects observed in the considered water bodies. It was shown that in the most contaminated water bodies the dose rates were high enough to cause the radiobiological effects.

POSTER PROGRAMME

ABSTRACTS

SESSION I

STUDY OF ENVIRONMENTAL RADIOACTIVITY IN CENTRAL AND SOUTHERN WEST BANK BY IN SITU GAMMA-RAY SPECTROSCOPY

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This work presents qualitative and quantitative evaluation of environmental radioactivity in the central and southern areas of the West Bank, Palestine. For this purpose, the technology of in situ gamma-ray spectroscopy is used with a scintillation of 7.6 3 7.6 cm NaI(Tl) crystal connected to multichannel analyzer InSpector 2000 from Canberra instruments and laptop computer.

Gamma-ray spectra were collected using the detector placed 1 m above the ground surface. Calibration of the detection system for in situ measurements of gamma-emitting radionuclides in open terrain is performed theoretically using Monte Carlo techniques. Measurements are conducted in 18 locations in 3 regions across the West Bank. The vast majority of identified radionuclides are naturally occurring gamma-emitting sources (the decay products of ^{238}U, ^{232}Th and ^{40}K). The only identified anthropogenic radionuclide is ^{137}Cs. Activity concentrations of ^{40}K, ^{238}U, ^{232}Th as well as the total outdoor gamma dose rate from these radionuclides were determined from the gamma-ray spectra. The highest activity concentrations of the three primordial radionuclides were 203 Bq/ kg for ^{40}K, 32 Bq/ kg for ^{238}U and 30 Bq/ kg for ^{232}Th. The total outdoor gamma dose rate calculated for the whole study area at 1 m above ground ranged from 6 to 30 nGy/h with a mean of 18+7 nGy/h, which represents about 30% of the world average value.

A SIMPLE DOSIMETER FOR KERMA MEASUREMENT BASED ON COMMERCIAL PIN PHOTO DIODES

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A new dosimeter for measurement of radiation dose from neutron and ionization radiation is presented. The dosimeter (kerma meter) uses as its active element commercial PIN diodes with long base. Later provide a maximal dependence of the minority carriers life time versus absorbed dose. The characteristics of the dosimeter were measured for several types of commercial diodes. Device can be useful in many environmental or industrial applications.

The described device - simple dosimeter (kerma meter) - can be employed for the measurement of absorbed dose in wide range of doses and energies by using different type of diodes with different sensitivities. It can be also used as an independent measuring device with very simple control and also for remote measurement/monitoring of dose using external software of PC. Using external software it is possible to use functions for direct dose calculation (including NIEL model) and alarm message email agent which allow send e-mail to defined address when desired dose was reached. The hardware of dosimeter has very low cost and software for dosimeter is a freeware.

FOUR PASSIVE SAMPLING ELEMENTS (QUATERFOIL)

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Four passive sampling elements (termed quatrefoil) have been recently developed, which transform volume-distributed radionuclides (Bq/m^3) into surface-distributed radionuclides (Bq/cm^2). For what concerns airborne particles, these elements exploit the mechanisms surface-deposition for the selective sampling of particles with nanometer- and micrometer-sizes respectively. In the case of radioactive gases, the sampling occurs by trapping the nanometer particles formed by atoms and/or molecules into nanoholes of technological advanced materials.
Once exposed, these samplers result in thin radiation sources which can be detected with any real-time or passive detector.
In particular, by using a large collecting-area sampler, characterized by low surface density (g/cm^2) and large specific surface (m^2/g), it is possible to measure radon and its decay products even by hand-held contamination monitors, which are rarely used for these applications.
Experimental results will be reported to demonstrate that it is finally possible to carry out the measurements of radon (and its decay products) indoors, in soil and in water by the pancake G.M. counter.
Emphasis will be given to those measurements, which are difficult, if not impossible, to carry out with existing technology, such as the assessment of the in-soil radon concentration over large areas, the measurement of the radon concentration directly in water, etc. Alternatively, these new passive samplers make it possible to use radon-decay products as tracers for the detection of all airborne nanoparticles, simply by a pancake Geiger –Muller counter.

DYNAMICS OF AIR POLLUTION WITH TRANSURANIC ELEMENTS IN THE SOUTH OF BELARUS

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The study on radioactive atmosphere pollution with transuranic elements in the republic of Belarus has been conducted since 1980-th till now. Before the Chernobyl disaster (April 1986), according to the experimental data, the concentration of radionuclides in the near ground air was: ^{239,240}Pu - 3.2×10^{-9} Bq/m^3, ^{238}Pu - 0.10×10^{-9} Bq/m^3. Right after the Chernobyl disaster a significant increase in the content of radionuclides (approximately in 106 times in comparison with the level before the accident) was registered. After a sharp decrease in the specific activity of air in may-august 1986 the phase of a gradual self-purification of the near ground air from radionuclides has started (in the early years after the accident the half-life period of plutonium-239,-240 was 14.2 months).

Nowadays, radioactive air pollution is formed under the influence of the processes of resuspension and secondary transport of radioactive particles that depend on various factors of natural and anthropogenic origin.

The findings shows that in the course of time a decrease in radionuclide concentration in the near ground air layer occurs due to migration through soil profile, accumulation by plants, and sorption on the surface of soil particles. Thus, redistribution and immobilization of radionuclides in various components of the biosphere occur that lead to a decrease in possibility of their transition to the air. The exceptions are those years in which there were numerous fires in the studied areas (1992, 2002).

Cycling changes in the content of technogeneous radionuclides in the near ground air with significant increase in spring-autumn period are observed in the course of a year. It is connected with the release of soil surface from snow in spring and vegetation in autumn, as well as with an intensive agricultural activity in areas adjacent to the resettlement zone. An average concentration of dust in the air of the resettlement zone is equal due to the absence of anthropogenic impact. At the same time it growths sharply in the residential zone, especially during agricultural activity. Therefore, in spring-autumn period, in spite of lower density of soil pollution with transuranic radionuclides, in areas with an intensive agricultural activity adjacent to the “resettlement zone”, the content of radionuclides in the air can reach and sometimes exceed the index for the “resettlement zone”.

The work was fulfilled within the framework of NATO project “Radioactive Pollution of the Territory of Belarus in the Polessie Radiation-Ecological Reserve” (SFP 983057).

NATURAL RADIOACTIVITY LEVELS (K, TH, AND RN) IN SOME AREAS OF PUNJAB, INDIA

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Radioactivity, natural and man made, is omnipresent in the earth's crust in different amounts. The soil on the earth's crust is a source of continuous exposure to human beings. ^{226}Ra, ^{232}Th and ^{40}K analysis has been carried out in soli samples collected from some areas of Punjab, India using gamma-ray spectrometry. The technique of gamma ray spectrometry was applied using high purity germanium gamma-ray detector and a PC based MCA. Radium equivalent activities are calculated for the analyzed samples to asses radiation hazards arising due to the use of these soil samples in construction of dwellings. The measured activity in the in the soil ranges from 22.78 to 45.87 Bq kg^{-1}, 54.67 to 99.76 Bq kg^{-1} and 432.06 to 608.97 Bq kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K with mean values of 34.13, 78.05 and 521.41 Bq kg^{-1}respectively. It has been observed that on the average the outdoor terrestrial gamma air absorbed dose rate is about 85.84 nGy h^{-1}.

RADIONUCLIDES IN THE DUST STORM PARTICLES ON EASTERN AND CENTRAL AREAS OF SAUDI ARABIA

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Dust particles can transfer radioactive nuclides close to populated areas, which contribute to urban air pollution and threaten the public health. In addition, this can be one of the main environmental impacts of radioactive exposure to human beings. Violent wind and dust storms are common in Saudi Arabia. For instance, on July 2009, a dust storm stretched from Iraq into the north eastern and the central areas of the kingdom. The present study reports the dust particles that were collected during and after this storm in five different locations using air filters. The measurements were carried out using a HPGe gamma spectrometry system for investigating the activity concentrations of ^{226}Ra, ^{228}Ra, ^{235}U, ^{238}U, and ^{40}K. The results were compared with the background readings for the same locations that were performed before.

ACTIVITY CONCENTRATIONS OF NATURAL RADIONUCLIDE MATERIALS IN ISFAHAN SPRING WATERS

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Background: Radioactivity in water is not a new phenomenon, having been presented to some extent since the earth was formed. Despite this history, radioactive materials in water above the standard level may be harmful to human health. Estimation of natural occurring radioactive materials level in spring waters is important from several points of views as they may be used for drinking or agriculture.

Materials and Methods: In this study 40 springs located at different location of Isfahan province were selected. These springs were distributed around the province. Water collection was performed two times in each month from each spring and during a year starting from March 2009 to the end of April 2010.

Two liters of water each time and from each spring were collected in prepared plastic bottles. The collected sample from each site was then allowed to stand for a minimum of 16 hours. From each bottle a sample of 100ml was poured into a refrigerator bag and again was left for about 24 hours. The samples were then left for 72 hours on the surface of a NaI(Tl) scintillator for activity and types of radioactive material determination. The activity of the samples were measured using a gamma ray spectrometer which consists of a 3x3 inches NaI(Tl) detector. The detector was coupled with a MCA board and winTMCApro 6 gamma spectrometer software. The whole gamma spectrometer was made by German company Target. The detector was shielded with adequate lead to reduce background radiation. The system was calibrated in terms of energy and counting efficiency using ^{137}Cs and ^{131}I sources.

Results and discussions: The obtained spectra were analyzed and the main radioactive concentration founded were corresponded with the spectral peaks of 1.46MeV(^{40}K0, 1.76MeV(^{204}Bi) and 2.61MeV ^{208}Tl. These peaks were considered for the activity evaluation of ^{40}K, ^{238}U series and ^{232}Th series respectively. The resolution of the crystal detector was 6% for ^{40}K, 4.4% for ^{232}Th and 5.5% for ^{238}U series.

The activity ranges of the above radioactive materials from different sources were 43.6±17.7 Bq/L for ^{40}K, 35.2±12.4 Bq/L for ^{238}U and 18.1±6.7 Bq/L for ^{232}Th. There was no meaningful difference in the measured radioactive concentration from different samples for each spring. The consequences of these amounts of radioactive concentrations are discussed.

USING A LOW-LEVEL GAMMA SPECTROSCOPY SYSTEM IN THE PERIPHERY OF A RESEARCH REACTOR

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At the Institute of Atomic and Subatomic Physics in Vienna, a 250 kWth TRIGA Mark II research reactor is operated. Beside the direct emission of gamma radiation, radio-nuclides in the form of activated gases (e.g. ^{41}Ar with a half live of 1.83h) are emitted in the periphery of the reactor. On the other hand, a gamma spectroscopy system for low-level counting should work well in spite of the higher background produced by the reactor. Therefore, a place must be found where the effects of the reactor can be minimized, e.g. in the basement. However, certain locations, e.g. the basement, can have other problems, such as the impact of natural radiation on the system resulting e.g. from ^{40}K or diffusing ^{222}Rn and its daughters. Therefore, different measurements were made with the gamma spectroscopy system to determine the influence of the reactor and natural gamma radiation to find the best place for operation. The measurements included different locations (e.g. reactor hall, first basement, second basement) and different ventilation conditions (room ventilation, additional nitrogen ventilation of the measurement chamber) with and without shielding of the detector. Subsequently, the obtained background spectra were compared to analyze the influence of the reactor on the system. The data of these measurements and the impact of the shielding measures are presented in this paper.

FAST NEUTRON SPECTROMETRY USING THICK THRESHOLD DETECTORS

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This paper discusses the use of thick threshold activation detectors for the characterization of low intensity neutron fields. This technique has been applied for the determination of the spectral emission of a low activity (1Ci) Am-Be source.

The reaction rates induced by the neutrons emitted by this source in different thick metallic targets (Al, Si, Fe, In) have been measured in the following reactions: ^{27}Al(n,p)^{27}Mg, ^{27}Al(n, α)^{24}Na, ^{28}Si(n,p)^{28}Al, ^{56}Fe(n, p)^{56}Mn, ^{115}In(n, n')^{115m}In and ^{115}In(n, γ)^{116m}In.

Each measured reaction rate corresponding to a threshold detector response depends on the spectral emission of the source via a correcting factor. This factor, which takes into account the

source detector geometry and the neutron attenuation and diffusion by the detectors, has been determined by Monte Carlo simulation using MCNP5 code.

The spectral emission of the neutron source has been generated from the response matrix of the threshold detectors by using different neutron spectrum unfolding methods (Stayn'l, Gravel and Maxed). A fairly good agreement with the ISO assumed spectrum has been achieved.

RA-228/RA-226 ACTIVITY RATIO IN GROUNDWATER AROUND FUJI VOLCANO, JAPAN

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Young groundwater age less than 100 years is possible to be obtained from environmental radioactivity with short half life, $^{3}H+^{3}He$ [1], ^{85}Kr [2], or chemical material, CFC-12 [3]. Age determination of young groundwater by some method, $^{3}H+^{3}He$, ^{85}Kr, and CFC, has both advantages and disadvantages, but the disadvantages of the individual methods can be offset by using multiple tracers. Therefore, development of a lot of groundwater techniques of age determination is desired.

^{226}Ra and ^{228}Radium are progeny from ^{238}U and ^{232}Th, respectively. The ^{226}Ra and ^{228}Ra in ground water are supplied from relevant rock which contact with groundwater. We aim that new groundwater age obtain from $^{228}Ra/^{226}Ra$ in groundwater and relevant rock. The method applied for Kakitagawa around Fuji Volcano, Japan, and our method compared with $^{3}H+^{3}He$ age determination. The residence time of Kakitagawa river water estimated from the $^{228}Ra/^{226}Ra$ activity ratio in river water and relevant rock agree well with $^{3}H+^{3}He$ age, suggesting that $^{228}Ra/^{226}Ra$ of groundwater could be used as a tool of residence time estimation of groundwater.

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DOSE EFFECTS AND IMPACT ASSESSMENT OF Cs-137 ON NATURAL MARINE ORGANISMS BY USE OF ENVIRONMENTAL MODELS

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Mathematical modelling is a very important and useful tool for the study and the prediction of the behaviour of pollutants in relation to the local ecosystem features, and can be used for impact assessment on marine biota.

In the present study, the radiological impact assessment of a selected area in the North Aegean Sea, Greece is carried out based on gamma spectrometry measurements of radionuclide activity concentrations in seawater and sediment, simulated in adequate models.

The measured radionuclide activity concentrations and/or published data were applied to a full CFD (Computational Fluid Dynamics) and a three-dimensional general deterministic model was developed to simulate and study the time-dependent behavior of ^{137}Cs in marine habitats. The simulated data are evaluated in terms of the conceptual model of dose rate effects and our published data of the cytogenetic effects of radionuclides on natural marine organisms.

For the study purposes, different exposure spaces (infinitive and semi-infinitive in sea water and sediment and the seawater-sediment interface, respectively) are used for the external dose rate estimations to natural marine biota whereas, our published data of concentration factors are used to estimate the internal dose rates for Fish of various habitats (demersal, demersal-pelagic and pelagic). The respective impact on the cytogenetic level is evaluated, as well.

MONTE CARLO SIMULATIONS OF BACKGROUND CHARACTERISTICS OF GE-DETECTORS IN UNDERGROUND LABORATORIES

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An increasing number of experiments have been devoted to the detection of very rare events, e.g. in double beta-decay, dark matter and neutrino experiments, as well as in environmental physics. Their common feature is a utilization of high sensitive low-level counting spectrometers, operating very often underground. If a detector was constructed from selected radioactivity free materials, the dominating background component in a surface or shallow underground laboratory would be cosmic rays. The flux of soft component cosmic-ray particles (electrons, positrons, gamma-rays) can be considerably decreased due to electromagnetic showers in materials with high atomic number, e.g. lead, iron, copper, etc. On the other hand, the flux of hard component particles (muons) can be decreased only by installation of detectors deep underground, or by using an anti-cosmic (anticoincidence) shielding. For the background optimisation of a counting system it is useful to use a Monte Carlo simulation, so the background characteristics can be estimated before constructing a counting system. The aim of our work has been a development of a computing code that would allow to compute background components of low-level HPGe γ-spectrometers placed underground, optionally equipped with anti-cosmic shield. The simulation code is based on the CERN's GEANT 4, and for a generator of cosmic-ray particles the Hangman's cosmic-ray shower library has been used. Before performing a large number of simulations for various shields, we had tested the developed code by comparing the obtained results for existing set-ups. The optimum set-up of shields was then tested for detectors placed at various underground depths.

I-131 LEVELS IN THE SEWAGE TREATMENT FACILITY AND RIVER

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The objective of our study is to determine the environmental consequences of discharges of ^{131}I from hospitals into sewage treatment facility and river.

We measured ^{131}I levels in sewage, sludge, river water, river sediment, and aquatic plant collected at the Gap River and the sewage treatment facility in Daejeon between 2008 and 2009, and performed a series of calculation to estimate ^{131}I discharge from patients into the sewage treatment facility.

^{131}I levels in water, sediment, and aquatic plant within 10 km from the facility show in the ranges of 0.386 1.129 Bq/L, 0.287 8.73 Bq/kg, 46.7 125 Bq/kg, respectively. The concentration fact in aquatic plant and sediment distribution coefficient were estimated to be 155±120, 4±5, respectively. The radioactivity levels of ^{131}I in sewage for inflow and discharge point each treatment facility were found to be reasonably constant. Measured ^{131}I level of dewatered sludge cake and digested sludge was 2186±317 Bq/kg, 217±20 Bq/kg.

Using sewage volume, administered activity of ^{131}I, datasets for time-dependent functions to represent the predicted quantities in ICRP publication 78, ^{131}I activity in the input points at the sewage treatment facility were calculated. The ratios between the estimated ^{131}I activity via the model and measured ^{131}I activity were 0.62 for the first input point, 0.82 for the second input point.

NOVEL SMEAR METHOD USING SMEAR-KUN

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The criteria concerning the clearance of materials contaminated with radioactivity were published by the IAEA and ICRP. The wipe sampling using smear paper is useful for evaluation of removable contamination with radioactivity. The activity on object's surface prior to wipe sampling is obtained by dividing the collection efficiency (CE) into the activity on the smear paper. The high accuracy of CE is important. The wipe pressure concerning wipe sampling may influence the CE. The ISO presents the wipe sampling guideline that the smear paper should be pressed moderately against the surface, using fingertips or instrument designed to ensure uniform and constant pressure. The wipe sampling is generally carried out by the method using fingertips. It is difficult to control the wipe pressure by fingertips. Therefore the instrument in a constant pressure (SMEAR-KUN) was manufactured. The objective of this study is analyzing the influence of wipe pressure upon the CE using the SMEAR-KUN.

The smear papers were fixed to SMEAR-KUN. The test surface of linoleum seats was sprayed with ink included ^{32}P-phosphoric acid by the printer. The activity on test surface was wiped in a pressure by SMEAR-KUN. The activity on the smear paper was measured by the imaging plate-Bass system. The wipe sampling and measurement of the activity was repeated 5 times at each wipe pressure. The activity per unit area was traced at pressures from 0.3 to 2.2 kgf/cm^2. The CE and the fraction were analyzed with the method of least squares. The CE depended on the wipe pressure.

PLUTONIUM SIGNATURE IN THE TROPICAL NORTHWEST PACIFIC USING A MODERN CORAL ARCHIVE

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Coral skeletons are excellent tools for retrospective studies of the historical Pu signature in the marine environment. Plutonium is incorporated in the coral skeleton during growth, with a constant relationship between Pu in the coral and in the surrounding seawater. Sources of Pu isotopes to the marine environment are well defined, both spatially and temporally, which makes Pu a potential tracer for oceanic processes. Plutonium in the Pacific Ocean is mainly from two contrasting sources, global fallout and close-in fallout from the former US Pacific Proving Grounds (PPG) in the Marshall Islands. Remobilised Pu from the seabed around the Marshall Islands is continuously leached into the surrounding seawater and transported long distances along the westward flowing North Equatorial Current (NEC) and the subsequent Kuroshio Current (KC). Activity concentrations of $^{239+240}$Pu and ^{240}Pu/^{239}Pu atom ratios were determined in banded skeletons of a dated (1960–2002) modern coral from the Chuuk Islands to identify the historical Pu signature in the tropical Northwest Pacific and estimate the contributions from the two main Pu sources. The Pu isotopes, ^{239}Pu and ^{240}Pu, were determined in the coral bands using multi-collector inductively coupled plasma mass spectrometry (MC-ICP-MS) combined with a high-efficiency sample introduction system. A combination of anion-exchange and extraction chromatography was utilised to ensure removal of any interferences from ^{238}U. The overall average ^{240}Pu/^{239}Pu atom ratio was 0.237±0.005, reflecting a higher contribution from remobilised Pu from the Marshall Islands. Remobilised Pu showed a variable contribution over time with a trend of increasing contribution in recent coral bands (1981–2002). The estimated contribution from the PPG Pu in these recent coral bands was 74% with an average ^{240}Pu/^{239}Pu atom ratio of 0.284±0.020.

VARIATIONS OF PB-210 CONCENTRATIONS IN SURFACE AIR AT THESSALONIKI, NORTHERN GREECE (40°N)

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Atmospheric concentrations of ^{210}Pb were measured over the year 2009 in ground level air at Thessaloniki, Northern Greece (40°38'N, 22°58'E). The mean activity concentrations of ^{210}Pb in surface air have been found to be 671 ± 275 μBq m-3. The highest values of monthly atmospheric concentrations of ^{210}Pb were observed in the autumn and the lowest in the spring period. The higher values of ^{210}Pb during autumn were attributed to frequent inversion conditions of the surface layers, resulting in a build-up (enrichment) of radon and its decay products in ground-level air. The lower values during the winter months might be due to the low emanation of radon from the frozen or snow-covered soil. The minima of ^{210}Pb concentrations during spring might reflect on higher washout, since in the region of Thessaloniki, the higher precipitation amount takes place during the spring months and the emanation of radon is strongly diminished when the soil is saturated with water, resulting in less production of ^{210}Pb near ground level air. The relative high values during the summer period were attributed to the maximum observed ^{222}Rn exhalation from the ground surface during the warm summer months. The observed high values would be even higher in absent of vertical mixing within the troposphere during that period, which results in a slight depletion of ^{210}Pb. The positive correlation that was observed between ^{210}Pb and ^{7}Be only for the summer period reflects the increase of both radionuclides during summer, suggesting that these two radionuclides could be used together as tracers of environmental processes.

TIME LAG BETWEEN THE TROPOPAUSE HEIGHT AND THE LEVELS OF BE-7 CONCENTRATION IN SURFACE AIR

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^{7}Be is a relative short-lived ($t_{1/2}$ = 53.3 d) cosmic-ray produced radionuclide, which is formed in the upper troposphere and lower stratosphere by spallation reactions of light atmospheric nuclei. Its flux to the Earth's surface varies with the 11-year solar cycle and has a latitudinal dependence. The concentration of ^{7}Be at surface air has been determined over the year 2009 in the region of Thessaloniki, Greece at 40°62' N, 22°95' E. In geomagnetic latitudes over λ=40°N, the elevation of tropopause during the warm summer months and the vertical removal of air masses within the troposphere are stronger. The tropopause height is a complex atmospheric factor and this is because it is affected by many variables such as the temperature and the pressure measured in

close air levels but also by the geopotential height and temperature of the two closest pressure levels. The tropopause height for the latitude of investigation was calculated for every single day of 2009. The elevation of the tropopause causes greater mixture of the air masses resulting in higher concentration levels for ^{7}Be. Positive correlations were revealed between the activity concentrations of ^{7}Be and the tropopause height (0.94, $p<0.0001$) and also between ^{7}Be concentrations and the temperature T (°C) ($R=0.97$, $p<0.001$), confirming that the increased rate of vertical transport within the troposphere, especially during warmer months, has as a result to carry down to the surface layer air masses enriched in ^{7}Be. But the thing is that atmosphere does not respond immediately to the changes of meteorological factors. So, we are expecting a lag between these two maximums that might be from hours (highly unlikely) to days or weeks. The time lag between the elevation of the tropopause and levels of ^{7}Be concentration represents the time we have to wait until ^{7}Be concentration levels in the surface air respond to the change of the tropopause height and this is the next step in order to understand relationship between ^{7}Be concentrations and the meteorological factors. The first results will be presented in October 2010.

DETERMINATION OF URANIUM CONCENTRATIONS IN GROUND WATER SAMPLES OF NORTHERN GREECE

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The activity concentrations of ^{238}U and ^{234}U have been determined by a-radiometric analysis in groundwater samples of springs and deep wells from the region of Northern Greece. The analysis was performed by alpha spectroscopy (using Si-Semiconductor detectors) after pre-concentration and separation of uranium by cation exchange (Chelex 100 resin) and finally its electro-deposition on stainless steel discs. According to the experimental results the uranium concentration in deep wells and springs varies strongly between 0.15 and 7.66 μg l^{-1}. Generally the springs present higher uranium concentrations than the deep wells, except of the Apollonia spring, which has shown the lowest value of 0.15 mg l^{-1}. Uranium concentration in natural waters is affected by a number of factors, such as the lithostratigraphic formations, their mineral content, the chemical behavior of the nuclide, the origin of a groundwater etc. ^{238}U and ^{234}U activity concentrations ranged between 1.8-95.3 mBq l^{-1} and 1.7-160.1 mBq l^{-1} respectively. The obtained isotopic ratio ^{234}U/^{238}U varies between 0.95 and 1.74 which means that the two isotopes are not in radioactive equilibrium. The highest ^{234}U/^{238}U activity ratio values correspond to Langada springs, indicating most probably old-type waters. On the other hand, groundwaters from wells with relatively low uranium activity concentrations and ^{234}U/^{238}U isotopic ratios, point to the presence of younger waters with a stronger contribution of a local recharge component to the groundwater.

NATURAL RADIOACTIVITY AND ASSOCIATED RADIATION HAZARDS PRESENT IN SOME ALGERIAN BUILDING MATERIALS

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Radioactivity is present in the atmosphere, the earth's crust and even in our food. It can be of different origin, e.g. natural, artificial or cosmic. The characterization of radioactivity level of various materials' samples is of great interest for environmental monitoring and for fundamental physics experiments. The building materials, containing natural radioactive elements ^{235}U, ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K, are good examples of radiation sources which we are exposed to every day. In this work we have measured the specific activity in $Bq.kg^{-1}$ of some building materials from East Algeria: Portland cement, white cement, breeze-block, red brick, and two kaolins. The measurements were made using ultra-low background, high-resolution gamma-ray spectroscopy. This non destructive method is best suited for the identification and quantification of different radionuclides in a sample. The measured specific activities range from 14 to 145 $Bq.kg^{-1}$, from 0.78 to 104 $Bq.kg^{-1}$ and from 4 to 681 $Bq.kg^{-1}$ for ^{238}U, ^{232}Th and ^{40}K, respectively. These values allow us to calculate the radiological protection factors: the radium equivalent Raeq, the external hazard index H_{ex} and the internal hazard index H_{in}, the absorbed dose rate D, and the annual effective dose rate E. These factors have enabled us to estimate the risk of population exposure to natural radioactivity due to construction materials. All studied building materials have shown Raeq ranged between 25 $Bq.kg^{-1}$ and 348 $Bq.kg^{-1}$; lower than the limit value of 370 $Bq.kg^{-1}$.

SYSTEMATICAL INVESTIGATIONS OF Cs-137 CONCENTRATION IN SOILS IN BULGARIA

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Systematical investigations of ^{137}Cs activity concentration in soils in Bulgaria were performed for the first time. Possible areas of the country contaminated with ^{137}Cs were determined by meteorological data for the period after the Chernobyl accident. The radio-nuclide content of soil samples was determined by means of high-resolution gamma-ray spectroscopy. This paper presents a comparison between the results of measuring the activity concentration of ^{137}Cs in two areas visited by many Bulgarian and foreign tourists: National Park "Central Balkan", an area

contaminated by ^{137}Cs and the Razlog Valley, uncontaminated area. The obtained results show that the activity concentration of ^{137}Cs in the Razlog Valley is comparable to the mean concentration of 137Cs in Bulgaria (25 Bq kg^{-1}). The activity concentration of ^{137}Cs in National Park is about four times higher than that in the Razlog valley, indicating contamination by ^{137}Cs. There is clearly expressed distribution of the activity concentration of ^{137}Cs in altitude. It is related to the altitude of rain clouds, which are the main contributors to the contamination in the area of National Park after the Chernobyl accident. The additional dose rate caused by this fallout was estimated and compared with the results obtained in other countries.

Cs-137 ACTIVITY CONCENTRATIONS IN WILD BOAR MEAT MAY STILL EXCEED THE PERMITTED LEVELS

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The radiocaesium activity concentrations may still remain high in natural products such as game meat, wild mushrooms, and forest berries even more than two decades after the Chernobyl accident. The results of regular control studies of game meat conducted in Poland showed wild boars as the most contaminated game animals. It is well documented that some mushrooms, readily consumed by animals, show high ability to accumulate caesium radioisotopes. Bay bolete, one of the most wide-spread mushroom species in Poland, reveals a unique radiocaesium accumulation feature. Pigments from the bay bolete cap cuticle (badion A and norbadion A) can complex potassium and its chemical analog caesium. Moreover, deer truffle which also contains particularly high levels of radiocaesium, could be another radionuclide source for wild boars. These mushrooms grow in a depth of 6–8 cm in spruce forest soil, which corresponds to O_h/A_h (organic layer/mineral layer) horizon where the peak of ^{137}Cs activity is still observed. Furthermore, animals consuming deer truffles could digest contaminated soil components. Of 94 samples of wild boar meat analysed by Veterinary Inspection in 2008–2009, 2 exceeded the permitted levels (600 Bq/kg). Hence, some precautions should be taken in populations with elevated intake of wild boar meat. Moreover, since each hunted wild boar is examined for trichinellosis, measurements of radiocaesium concentrations in these animals may be advised for enhancing consumer safety.

THE RADIOLOGICAL IMPACT OF A PHOSPHOGYPSUM CONTAMINATED AREA INSIDE THE LAGOON OF VENICE: RN-222 MONITORING

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For about 20 years, between the 60's and the 80's of the last century, in the Passo a Campalto area (Lagoon of Venice - Italy) about 400,000 m3 of phosphogypsum (PG) were deposited at the border of the Lagoon and next to urban areas without any environmental control.

These materials are a by-product formed during the wet processing of phosphate rocks by sulphuric acid and have a significant environmental impact due to their abundance and their chemical-physical and radiochemical characteristics. The PG contains both chemical elements which are considered to be dangerous for the ecosystems and natural radionuclides whose concentrations are much higher if compared to those typical for the Earth's crust.

This unrestored deposit caused for many years the dispersion of radionuclides in the environment due to the tidal erosion, the re-suspension of radioactive inhalable dusts, the uncontrolled radon exhalation and the bioaccumulation of some radionuclides in the lagoon environment.

After a decision of the appointed authorities, the Venice Water Authority (Ministry of Infrastructure and Transport) projected the restoration of the site resulting in the complete isolation of the entire volume of contaminated materials from the environmental system.

The entire project is specific for the particular features of the site and it has required the improvement of analytical, sampling and measurement techniques in order to verify the effectiveness of the restoration. This study concerns the project and the execution of the surveys, in particular the check of the effectiveness of the inhibition of radon exhalation.

The results show the efficacy of the intervention: concentrations in air and exhalation values from the restored area, measured during surveys, are well in agreement with those of non contaminated soils.

OPENING OF THE CLOSED WATER AREA AND CONSEQUENT CHANGES OF RA-228/RA-226 RATIOS IN BRACKISH LAKE NAKAUMI, SOUTHWEST JAPAN

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This report is the first attempt of Radium measurement to understand Ra behavior with respect to the seasonal change of brackish Lake Nakaumi, which is associated with the closed area (the Honjyo area) over 27 years. This closed area has been formed a different water character from the main body of Lake Nakaumi, but the dike of this closed area was artificially opened in May, 2009, and subsequently introduced the more saline coastal marine water through the Sakai Channel from the Sea of Japan. A total of 7 sites were set to examine the characteristics of Activity Ratio (AR) of $^{228}Ra/^{226}Ra$ in this lake. Mn fiber was submerged at different depths for 4 days to 1 week at each site, and sampling work has been carried out every month from November, 2007 onward.

The ARs of $^{228}Ra/^{226}Ra$ in both Honjyo closed area and Lake Nakaumi have very clear seasonal variation with high in summer and low in winter. Before the opening event, the AR distribution pattern at each site showed well-tuned seasonal variation in the surface water, but there was a little phase difference for one or two months in deep water. Particularly, the Honjyo closed area is characterized by high ARs for both surface and deep waters. The AR difference between the Honjyo and Nakaumi surface waters was usually ~0.5. The high ARs in the Honjyo area must have been caused by a limited exchange with the Nakaumi water. The AR in the Sakai Channel was usually lower, which may have been influenced by originally low-AR marine water. The ARs in Nakaumi water was a middle value between the Honjyo area and the Sakai Channel and was varied in harmony with those from the two areas. Assuming the high Honjyo ARs were resulted from the release from bottom sediment and they were not diluted by other waters, the Nakaumi water would be the same ARs as those of the Honjyo area. However, the ARs of the Nakaumi were lower than those of the Honjyo; this may have resulted from a half percent dilution by coastal marine water.

After the opening event, the ARs of the deep Honjyo water show more distinct monthly variations, while the ARs in the surface water show a similar value and nearly the same distribution pattern in both Honjyo and Lake Nakaumi. The two-years monitoring of ^{228}Ra and ^{226}Ra indicates the AR is very useful to understand the changes of water character and its dynamic movement of coastal lagoon water.

SPATIAL DISTRIBUTIONS OF RA-226, RA-228, AND CS-137 IN THE SOUTHWESTERN AREA OF THE SEA OF OKHOTSK

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The Sea of Okhotsk, one of the largest marginal seas of the northwestern North Pacific, is mainly connected to the North Pacific through the Kuril Straits, and the Sea of Japan by the very shallow Soya Strait. In the northwest of the Okhotsk, rapid sea-ice formation leads to production of the Dense Shelf Water (DSW), which ventilates below the surface and joins to the Okhotsk Sea Intermediate Water (OSIW). OSIW also plays an important role to form the North Pacific Intermediate Water (NPIW). Therefore, the migration pattern of OSIW has been extensively studied in this 15 years using various techniques.

Various radionuclides in seawater have been used as powerful tracers for studying geochemical cycles in marine environments. However, existing data records of radionuclides in the Sea of Okhotsk are not sufficient to allow investigating the details of water circulations.

To investigate the spatial distributions of ^{226}Ra, ^{228}Ra, and ^{137}Cs in this area, we collected 14 seawater samples (~60 L) at 5, 10, 50, 100, 150, 200, 250, 500, 750, 1000, 1250, 1500, 1650, and 1800 m depth at the southwestern area of the Sea of Okhotsk (*SY09C*; N45o01', E145o01'; 1850 m depth) together with 8 surface waters (~20 L) around Hokkaido, Northern Japan (Sta. 1-8) during the Soyo Maru expedition (Jul.-Aug. 2009). Activities of ^{226}Ra, ^{228}Ra, and ^{137}Cs were measured applying low-background -spectrometry combined with convenient minimal radiochemical processing.

Vertical changes of ^{226}Ra (~3 mBq/L), ^{228}Ra (~0.5 mBq/L), and ^{137}Cs (~1 mBq/L) activities in OSIW (~200-500 m) are small and, in contrast to other oceans, ^{226}Ra activity level of OSIW is markedly higher. From distributions of these nuclides, we clarify the origin and flow pattern of OSIW.

SEDIMENTATION RATES IN KAGOSHIMA BAY, SOUTHWESTERN JAPAN, USING PB-210 METHOD

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Kagoshima Bay is located in Southwestern Japan. This bay including some submerged calderas has two deep basins connected by shallow channel. To understand the pattern of sedimentation rates as fundamental physical parameter of coastal environment, the ^{210}Pb dating method was employed to core samples collected from this bay.

Sediment core samples were collected at four sites in Kagoshima Bay in August 2002 (Stn. 5', 21, 27 and 36) using an acrylic pipe corer. Each core (5-15 cm long) was cut into 1 cm-thick slices. After being dried and ground, ^{210}Pb and ^{226}Ra activities were measured by γ-spectrometry using Ge-detectors. Measuring the sedimentation rate using the 210Pb method is based on atmospherically derived ^{210}Pb, which is also referred to as excess ^{210}Pb (ex^{210}Pb; ^{210}Pb – ^{226}Ra).

Sedimentation rate varied at each location within the bay (0.08-0.30 g·cm-2·yr^{-1}), and the rate at the bay-head area was less than that at the centre of the bay. At Stn.27, the difference between the upper (0-5 cm; 0.27 g·cm-2·yr^{-1}) and lower layers (>5 cm; 1.0 g·cm-2·yr^{-1}) of the ex^{210}Pb profile indicated a disruption in constant sedimentation at the site. The low ex^{210}Pb activity at the sediment surface and low ex^{210}Pb inventory in the area of the bay-head imply that ex^{210}Pb is not easily deposited via the water column in this area.

EVALUATION OF THE ANTHROPOGENIC EMISSION OF BI-210 AND PO-210 ON THE BASE OF BI-210/PB-210 AND PO-210/PB-210 RATIOS IN THE URBAN AIR

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Evaluation of aerosol resident time, may add valuable information about the spread of pollutants in the atmosphere. Equations used for the calculation of resident time of aerosols on the basis of isotopic ratios of ^{210}Po/^{210}Pb and ^{210}Bi/^{210}Pb in the one compartment model assume that the only source of ^{210}Bi and ^{210}Po radionuclide are decays of ^{210}Pb->^{210}Bi->^{210}Po on the surface of the dust particles in the air.

This assumption does not take into account the possibility of additional emission of radionuclides from other sources such as re-suspension of soil in summer, or combustion of coal in winter. The aim of this work was checking possible input of intense coal combustion to the resulting ^{210}Pb, ^{210}Bi and ^{210}Po concentration in the urban air. For these propose, we have added en anthropogenic component to the steady state equilibrium equations used for description of the ^{210}Pb, ^{210}Bi and ^{210}Po radionuclide concentration.

As can be seen about 78% of ^{210}Po and 15 % of ^{210}Bi radionuclides in the urban air in Lodz during the winter can be attributed to the emissions connected with the burning of coal for heating and energetic purposes. The corrected resident times are close to these calculated on the base of ^{210}Bi/^{210}Pb ratios and varied from 1 to 13 days for the winter period. However, the ^{210}Bi/^{210}Pb method can be applied for aerosols with residence time < 30 days.

REMOVAL OF Cs, Sr, Pu AND Am FROM CONTAMINATED SOLUTIONS UNDER LABORATORY AND REAL CONDITIONS

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One of the most important environmental problems nowadays is contamination of the environment by radioactive and non radioactive pollutants and their harmful effects. The most commonly applied treatment technologies involve precipitation, ion exchange, evaporation and solvent extraction. Inorganic sorbents have been widely used to solve environmental problems and to minimize toxic effects of various pollutants due to their high selectivity, stability over a wide range of pH and temperatures as well as resistance to ionizing radiation. Thus, the application of inorganic sorbents such as ferrites and crystalline silicotitanates is one of the alternative technologies which can reduce the costs associated with waste disposal and minimize the contamination risk of the environment during processing and disposal of the radioactive waste. The aim of this study was a comparative assessment of synthetic materials obtained using different synthesis methods (co-precipitation or sol-gel and pure reagents or cheap and available Ukrainian raw materials) and natural sorptive materials in liquid waste treatment technologies to remove long-lived radionuclides Cs, Sr, Pu and Am. Titanium silicates, zirconium phosphates, titanium phosphates synthesized at the Ukrainian Institute for Sorption and Problems of Endoecology and iron oxides synthesized at the Institute of Physics (Lithuania) as well as the Triassic clay samples from a site mined for industrial exploitation known as the Šaltiškiai (North Lithuania) quarry were used in equilibrium and kinetic sorption experiments. The obtained results revealed that titanium silicates synthesized using $TiOSO_4$ without reference to the chosen method showed the highest sorption ability towards studied radionuclides. Magnetite and clay minerals showed better sorption ability towards americium. The K_d values ranged from $3.9 \cdot 10^2$ to $1.6 \cdot 10^5$

mL g^{-1} for Sr, from 6 to 4.1 · 10^4 mL g^{-1} for Cs, from 2.2 · 10^2 to 2.6 · 10^5 mL g^{-1} for Pu and from 50 to 1.6 · 10^4 mL g^{-1} for Am. The highest Pu K_d values (9 · 10^3–6.2 · 10^4 mL g^{-1}) and better kinetics were found for iron oxides.

Experiments performed with the fuel pond water at the Ignalina NPP and with the condensate water at the Chernobyl NPP "Shelter" indicated that K_d values obtained in the laboratory experiments do not usually correspond to the values obtained under the real conditions and this requires additional studies.

Acknowledgements: The research was supported by the Ukrainian Ministry of Education and Science of Ukraine as well as by the Agency for Science, Innovation and Technology of the Republic of Lithuania (contract No. TAP-36/2010) and the Research Council of Lithuania (contract No. TAP-54/2010).

A COMPARISON BETWEEN IN SITU AND LABORATORY MEASUREMENTS OF NATURALLY OCCURRING RADIOACTIVITY IN SOIL AS DONE WITH STANDARD NAI SCINTILLATION DETECTORS

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The accuracy of activity measurements done in situ depends on a number of complex factors. The aim of this study is to find experimental corrections for these factors by exploring the results of various gamma ray measurements done in the lab with 2x2 and 3x3 inch NaI(Tl) scintillation crystals. Comparisons are made between laboratory measurements done with different types of sample containers and those done in situ. Potential correction factors are extracted and evaluated. The results of this work wil be used as part of a preparatory study for a planned exploration project.

GEOCHEMISTRY OF RADIONUCLIDES IN GROUNDWATERS AT THE FORMER URANIUM AND RADIUM MINING REGION OF SABUGAL, PORTUGAL

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Recent concerns over the potential radiological hazards posed by the uranium mining and milling wastes have been the reason for radioactivity measurements in underground waters of County of Sabugal, central region of Portugal. Water samples collected in the former uranium mines, in nearby irrigation wells, and in village drinking water supplies were analyzed for uranium series radionuclides by wet radiochemistry and alpha spectrometry. Water from the Bica Mine contained 4.4 Bq L^{-1}, 1.5 Bq L^{-1}, and 0.48 Bq L^{-1} of dissolved ^{238}U, ^{226}Ra and ^{210}Po, respectively, and these were the highest concentrations measured in waters from this region. Water from irrigation wells generally showed concentrations below 5 x10^{-2} Bq L^{-1} for both ^{238}U and ^{226}Ra, although water from several wells near the Bica Mine showed enhanced concentrations of dissolved uranium, reaching 0.82 Bq L^{-1} of ^{238}U. Drinking water from public water supplies in the villages and towns contained ^{238}U, ^{226}Ra, ^{230}Th, ^{210}Po and ^{232}Th in concentrations below 5 x10^{-2} mBq L-1 each, and total alpha radioactivity generally less than 0.5 Bq L^{-1} as recommended for drinking water. Only one village water supply from a local spring exceeded with 1.12 Bq L^{-1} the recommended limit for alpha radioactivity in drinking water. The overall assessment of radioactivity in water indicates that water resources were not significantly contaminated by the historic uranium mining activities in the region. Nevertheless, mine waters from Bica Mine still require treatment to prevent dispersal of acid mine drainage and radionuclides into aquifers. This treatment is needed as oxic conditions and low pH-values facilitate the dissolution and migration of uranium, as predicted through modelling of uranium speciation and verified through measurements. Other mines nearby, with near neutral pH and anoxic waters show low dissolved concentrations of uranium.

RADIOXENON TIME SERIES AND METEOROLOGICAL PATTERN ANALYSIS FOR CTBT EVENT CATEGORISATION

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Understanding radioxenon time series and being able to distinguish anthropogenic from nuclear explosion signals are fundamental issues for the technical verification of the Com- prehensive Nuclear-Test-Ban Treaty. Every radioxenon event categorisation methodology must take into account the background at each monitoring site to uncover anomalies that may be related to nuclear explosions. Feedback induced by local meteorological patterns on the equipment and on the sampling procedures has been included in the analysis to improve a possible event categorisation scheme. The occurrence probability of radioxenon outliers has been estimated with a time series approach characterising and avoiding the influence of local meteorological patterns. A power spectrum estimator for radioxenon and meteorological time series was selected; the randomness of the radioxenon residual time series has been tested for white noise by Kolmogorov–Smirnov and Ljung– Box tests. This methodological approach was applied to radioxenon data collected at two monitoring sites located at St. John's, Canada and Charlottesville, USA, equipped with two different noble gas systems. It shows different feedback with local meteorological patterns and randomness for the radioxenon data recorded at the selected sites of St. John's and Charlottesville as well as a different occurrence probability of the outliers in the normalized radioxenon original and residual time series.

BACKGROUND OF RADON DAUGHTERS IN GAMMA-RAY SPECTROMETRIC MEASUREMENTS

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When samples from the environment are measured on gamma-ray spectrometers ^{226}Ra can be determined either directly from its peak occurring at the energy 186 keV or from the peaks belonging to radon daughters in the sample. The later method has the advantage that it is more sensitive. Radon daughters ^{214}Pb and ^{214}Bi radiate at several energies with the probability which much larger than the probability for emission of the gamma-rays in the decay of ^{226}Ra. If the activity of radon daughters in the sample is small a substantial part of the areas of peaks, signaling the presence of radon daughters in the spectrum may originate in the spectrometer background. To arrive at unbiased results the peak areas must be corrected for the background contribution.

Therefore background measurements are performed, which are used to determine the count rates in the peaks occurring in the spectra in the absence of the sample.

The background due to radon daughters originates from various sources, characterized by the location of radon daughters in the spectrometer. The spectrometer background due to radon daughters originates in the presence of ^{226}Ra the detector and the shielding, in the presence of radon daughters in the air filling the shield's cavity and, at high energies, in the incomplete attenuation of gamma-rays from the environment where the shield is situated. It was found that in some detectors background induced by radon daughters is constant in time whereas in others it exhibits strong correlation with the outside temperature.

SESSION II

I-129 IN MEDITERRANEAN SEA WATER - IAEA-418 CERTIFIED REFERENCE MATERIAL

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A Certified Reference Material (CRM) designed for the determination of ^{129}I in seawater, IAEA-418 (Mediterranean Sea water), is described and the results of certification are presented. The median of ^{129}I concentration with 95% confidence interval was chosen as the most reliable estimates of the true value. The median, given as the certified value, is $2.3 \cdot 10^{8}$ atom L^{-1} (95% confidence interval is (2.2-2.8) atom L^{-1}). The material is intended to be used for standardization procedures applied in Accelerator Mass Spectrometric (AMS) laboratories.

VERTICAL DISTRIBUTION OF NATURAL RADIONUCLIDES IN SOILS

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Low-level alpha spectrometry techniques using semiconductor detectors (PIPS) and liquid scintillation (LKB Quantulus 1220^{TM}) were used in order to determine the activity concentration of ^{238}U, ^{232}Th, ^{234}U, ^{230}Th, ^{226}Ra, and ^{210}Pb in soil samples. The soils were collected from an old disused uranium mine located in southwest Spain. The soils were selected with different levels of influence from the installation, in such a way that they have different levels of contamination. The vertical profiles in the soils (to 40 cm deep) were studied in order to evaluate the vertical distribution of the natural radionuclides. The possible contamination of subsurface waters depends strongly on vertical migration, and the transfer to plants (herbs, shrubs, and trees) also will depend on the distribution of the radionuclides in the root zone. The study of the activity ratios between radionuclides belonging to the same series allowed us to assess the different behaviours of the radionuclides involved. The vertical profiles for the radionuclides belonging to the ^{238}U series were

different at each sampling point, depending on the level of influence of the installation. However, the profiles per point were similar for the long-lived radionuclides of the ^{238}U series (^{238}U, ^{234}U, ^{230}Th, and ^{226}Ra). Also, a major disequilibrium was observed between ^{210}Pb and ^{226}Ra in the surface layer, due to ^{222}Rn emanation and subsequent surface deposition of ^{210}Pb. The comparison of the natural radionuclides profiles with the major elements and pH helped us to understand the migration of natural radionuclides in soils.

THE EFFECT OF ORGANIC AMENDMENT ON SORPTION MECHANISMS OF CESIUM AND COBALT IN TROPICAL SOILS

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This work aimed to investigate the mechanisms involved in the sorption of ^{137}Cs and ^{60}Co as a function of the physico-chemical properties in some types of Brazilian soils. It also evaluates the behavior of these radionuclides due to changes in soil properties promoted by organic amendment. The experimental study was conducted in a controlled area, where pots containing different types of soils (Ferralsol, Nitisol and Histisol) and different doses of organic amendment (no amendment; 2 kg m^{-2} and 4 kg m^{-2}) were spiked with ^{137}Cs and ^{60}Co. The organic amendment used in this experiment was obtained from the Compost Unit of Pinheiral (RJ, Brazil), which origin is from the leaves swept from the streets of the city. The mobility of these radionuclides in the soil was assessed through a sequential chemical extraction and desorption studies as a function of soil pH. The bioavailability was evaluated through the effective absorption of radionuclide by root crops (Raphanus sativus, L) expressed as soil to plant transfer factor. This study evidenced that very acid conditions (pH<2) released more than 80% of the total cobalt, independently of the organic matter content of the studied soils. Alkaline conditions (pH>9) were also capable to mobilize significant amount of ^{60}Co, but in this case higher content of organic matter, as occurs in Histisol, reduced the release. Under natural pH of the studied soils the lower transfer factor for ^{60}Co occurred when it received 4 kg m^{-2} of organic fertilizer or in Histisol, a soil with very high organic matter content. Soil to plant transfer factor (TF) for ^{60}Co was respectively 8.2, 6.4 and 2.0 for Ferralsol, Nitisol and Histisol and for ^{137}Cs they were 1.18, 0.13 and 0.23. Although extreme acid conditions and low organic matter content may mobilize both radionuclides, cobalt mobility was shown to be more sensitive to both parameters than cesium. These results suggest that other soil parameters interferes on ^{137}Cs behavior, possibly the concentration exchangeable K, clay mineral type and nutritional status as reported in the specialized literature.

ISOTOPIC TRACING OF GROUNDWATER AT ŽITNÝ OSTROV (SW SLOVAKIA)

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Geostatistical analysis of experimental isotope data has been carried out with the aim to study spatial variations in the distribution of water isotopes and radiocarbon in groundwater of Žitný ostrov (Rye Island), which is the largest reservoir (about 10 Gm^3) of groundwater in the Central Europe. Subsurface water profiles showed enriched $\delta^{18}O$ levels at around 20 m water depth and depleted values below 30 m, which are similar to those observed in the Danube River. The core of the subsurface ^{14}C profile represents contemporary groundwater with ^{14}C values above 80 pMC.

PARAMETER VALUES FOR THE PREDICTION OF RADIONUCLIDE TRANSFER IN TERRESTRIAL AND FRESHWATER ENVIRONMENTS

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The Technical Report Series (TRS) No. 472 derives from the TRS 364 Revision carried out within the framework of the IAEA International EMRAS (Environmental Modelling for Radiation Safety) Programme, Working Group 1 of Theme 1, in the years 2003–2007. This paper describes the approach taken to present the information on fruits in the TRS 364 Revision, supported by IAEA-TECDOC-1616, discusses the key transfer processes concerning the behaviour of radionuclides in fruits, and provides recommendations for research and modelling. Information presented in this section relate to fruit plants grown in agricultural ecosystems of temperate regions.

The Fruits information comprises a description of key transfer processes, concepts and conceptual models regarded as important for dose assessment, as well as relevant parameters for modelling radionuclide transfer in fruits. Parameter values have been collected from open literature, conference proceedings, institutional reports, books and international databases. The information generated in the years following the Chernobyl accident and the knowledge produced under the IAEA BIOMASS (Biosphere Modelling and Assessment) Programme in the years 1997–2000 has been mainly taken into account. However, given the scarce information available on the subject, the choice has been made to not reject any information.

Fruit contamination following a release to atmosphere can be the result of various processes: (i) direct deposition to exposed fruit surfaces, absorption by the fruit skin and transport to the

interior; (ii) deposition to exposed plant surfaces, absorption to interior and translocation to fruit; (iii) for perennial plants: remobilisation of radionuclides from the leaves to the over-wintering organs prior to leaf drop, followed by retranslocation from storage organs to other plant components at the resumption of growth; (iv) deposition to soil, vertical migration in the soil profile, root uptake and transfer to the fruit. The relative significance of each pathway after release of radionuclides depends upon the radionuclide, the kind of crop, the stage of plant development and the season at time of deposition. Furthermore, in agricultural ecosystems, the transfer of radionuclides to fruit is generally affected by human intervention, which includes horticultural practices, intended to modify physiology and translocation of nutrients, to achieve early cropping, high, early and sustained yield, and high fruit quality.

ESTIMATION OF PERMISSIBLE LEVELS OF RADIONUCLIDES DISCHARGES TO WATER BODIES USING THE RADIOECOLOGICAL AND HYGIENIC CRITERIA

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Estimation of permissible levels of radionuclides discharges to water bodies is important to ensure the radiation safety of population and environment. Method is presented for evaluation of radioecological consequences of radionuclides discharges to water bodies for humans and the reference species of aquatic biota.

Criteria for estimation of permissible discharges of radionuclides to water bodies include: (a) hygienic criteria, which require that the quota from the permissible dose limit should not be exceeded for the critical group of the population taking into account multiple pathways of exposure; (b) hygienic norms, which limited the activity concentrations of some radionuclides (^{137}Cs, ^{90}Sr) in food products; for example, for ^{137}Cs in fish such level in Russia is 130 Bq/kg and for ^{90}Sr 100 Bq/kg w.w; (c) limitations on radioactive contamination of bottom sediments and floodplain soils.

Radioecological criteria represent recommendations, that the sum of the internal and external dose rates to the reference species of biota should not exceed the reference levels, which ensure the radiation safety and stability of aquatic ecosystems. The following reference levels are considered: 1 mGy/day for aquatic animals (fish, birds, mollusks, etc.) and 10 mGy/day for aquatic plants. The principles for selection of reference species for aquatic ecosystems and reference levels of exposure are discussed.

An example of estimation of permissible levels of radionuclides discharges (^{3}H, ^{137}Cs, ^{60}Co) to the marine environment is considered. It is shown that for the most cases hygienic criteria limited the

permissible discharges of radionuclides to water bodies rather than radioecological criteria, although for radionuclides with high accumulation in bottom sediments and aquatic biota it is recommended to make an assessment of possible radiation exposure to reference species of biota.

TIME HISTORY OF TRITIUM CONCENTRATION IN THE SERUM OF CATTLE MILK UNDER VARIOUS FORMS OF ITS INCOME IN NATURAL CONDITIONS

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Tritium (^{3}H) is one of the major dose-forming radionuclides existing in the territory of the former Semipalatinsk test site (STS). Especially dangerous fact is the intake of ^{3}H in the human body via animal products, obtained while grazing animals in the areas contaminated with tritium at Degelen Mountain and Shagan River, which necessitates a thorough study of ^{3}H transition in various animal products.

The paper presents the results on the dynamics of T transition in milk serum under various conditions and timing of its uptake in the body of cattle with the components of the environment: air, water and vegetation. Studies were conducted at "Degelen" experimental site located in the former STS. As the object of investigation we selected one local cow of 8-9 years of age, live weight is 250-260 kg, with daily average milk yield of 6-8 kg. Throughout the study we used tether handling.

When ^{3}H is intaken with atmospheric air in the body of cattle within 12 days there is a linear increase in the concentration of ^{3}H in the serum of milk, while the equilibrium state is not reached. The results show that the aerial uptake of ^{3}H in the body of an animal can make a significant contribution to the formation of animal products contamination.

Dynamics of ^{3}H concentration in the serum of milk at a single-shot entry with the meadow grass and water is complex and ambiguous character, possibly caused by the physiological characteristics of the animal during the formation of milk, which requires additional research.

The research has determined that in Degelen Mountain, when ^{3}H is chronically uptaken with meadow grass the equilibrium state of its concentration in the serum of milk is reached on the fifth - the sixth day. When ^{3}H is chronically uptaken with atmospheric air and drinking water the equilibrium state of ^{3}H concentration has not been reached at selected time intervals.

In turn, reduction of ^{3}H concentration in the milk serum after chronic uptake of 3H with meadow grass is much slower than after chronic uptake with drinking water. Thus, reduction of ^{3}H concentration by 50% after long-term uptake with water occurred after ~ 2 days, after long-term uptake with meadow grass after ~ 14 days.

SPECIFIC CHARACTERISTICS OF RADIOACTIVE CONTAMINATION OF ENVIRONMENTAL ECOSYSTEM COMPONENTS OF THE TUNNEL WATERCOURSES IN DEGELEN MOUNTAINS OF SEMIPALATINSK TEST SITE

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In recent years, at "Degelen"test site, Semipalatinsk nuclear test site we conducted studies to specify the boundaries of distribution of artificial radionuclides ^{137}Cs, ^{90}Sr, and mainly, $^{239+240}$Pu in soils and subsoils of the stream valleys, as well as the outside,distribution patterns of which previously could not be detected. These studies were conducted in the valleys of the stream Baytles (tunnel No176) and inlet of Uzynbulak (tunnel No177). Also, studies were done on the nature of the spatial (both horizontal and vertical) distribution of artificial radionuclides in the soil of stream valleys of Degelen low-mountain massif. Based on years of diverse, integrated radioecological studies we revealed the peculiarities of radioactive contamination of natural ecosystems, stream valleys, exposed to the largest contamination with artificial radionuclides.

Based on years of diverse, integrated radioecological research in "Degelen" area we managed to reveal the peculiarities of radioactive contamination of natural ecosystems, stream valleys, exposed to the largest contamination with artificial radionuclides.

Distribution of radionuclides ^{137}Cs, ^{90}Sr, ^{241}Am and $^{239+240}$Pu in ecosystems the surface water - soil - groundwater is determined by the orientation of the total runoff from the upper to the lower reaches, but these processes are most clearly manifested in the valleys in the case of constant water seepage from the tunnels, located at the top. The basic amount of ^{137}Cs, taken out with water from the tunnel cavities, remains near the portals, often on gravel and rubble filter. ^{241}Am and $^{239+240}$Pu with water flow and subsurface runoff extends to several hundred meters from the portal, which is particularly noticeable in the case of the powerful water-saturated layer of soil, lying on the weathering crust of solid rock. Fairly high migration ability of ^{241}Am and $^{239+240}$Pu was unexpected, confirmed by data on their distribution across the riverbed as well as depth. Radionuclide ^{90}Sr, as the most soluble and mobile element, is able to spread with surface and groundwater within the unconsolidated sediments of the entire valley.

Despite the constant removal of radionuclides with water to the surfacewe did not observe extremely high concentrations in environmental media. The ratio of maximal specific activity of radionuclides in the water to specific activity of radionuclides in the soil at wellhead areas of the tunnels at this time does not exceed for ^{90}Sr - 10^{-3}, ^{137}Cs - 10^{-5}, ^{241}Am - 10^{-4} and $^{239+240}$Pu - 10^{-6}.

A specific focus of radionuclides migration in soils of the valleys is due to peculiar geomorphological conditions, but the distance they travel depends on the initial content in tunnel water, slope and flow intensity. Chemical properties of these elements are important in distribution of radionuclides, that is, the species of radionuclides in tunnels water, as well as their interaction with soil and terrain. It should be noted that the ecosystem surface water - soils - groundwater itself is very dynamic, and artificial radionuclides to be found in this system,are complementary to its non-equilibrium by processes of sorption, desorption.

The length of the watercourses of the tunnels usually can be tens and hundreds of meters, but the radionuclides remain within the mountain. The main reason for their sudden disappearance within the valleys is the presence of cracks, small and large faults, by which water is drained into an underground pool, however, reduction of soils contamination in the valleys of the streams from tunnel portals, especially with water seepage down the riverbed is caused not only by geological and geomorphological conditions of the site as well as chemical characteristics of these elements, but also physical and chemical properties of soil, which absorb and retain these radionuclides.

Thus, despite the complexity of the processes taking place in this ecosystem, artificial radionuclides remain within «Degelen» test site and do not flow beyond its borders with the surface, subsurface runoff.

PROMPT MEASUREMENT OF C-14 IN GASEOUS RELEASES OF NUCLEAR POWER PLANTS

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Radiocarbon is responsible for a major contribution to the collective effective dose from all radionuclides released by nuclear power plants (NPP) with light-water pressurized reactors (LWPR) during normal operation. The monitoring of gaseous and liquid releases from NPPs consists from routine determinations, performed by NPP's staff, and also extended, supervisory, sampling performed by research institutions. Monitoring of ^{14}C in stack air of NPPs is based on $^{14}CO_2$ accumulation in 3M NaOH solution. Combustible ^{14}C chemical forms (with prevailing $^{14}CH_4$) are transformed into $^{14}CO_2$ utilizing catalytic combustion. Activity of ^{14}C combustible forms is subsequently calculated as a difference of sum of all chemical forms and $^{14}CO_2$. Activities of ^{14}C are usually measured by liquid scintillation counting of $BaCO_3$ precipitate in suspension with scintillation cocktail. Several years ago we started to examine direct measurement of exposed NaOH solution as a preliminary determination of ^{14}C activity. For this purpose we are measuring in counting window above maximal energy of tritium beta emissions (^{3}H occurs in such samples frequently). To avoid overestimation given by presence of other interfering radionuclides we are applying indication methods based on: (1) spectrum check in regions above maximal energy of ^{14}C and (2) repeated measurement one week later at minimum. The value obtained by "$BaCO_3$ routine" would be preferred when presence of interfering radionuclides will be indicated. In our contribution the results of ^{14}C determination utilizing $BaCO_3$ precipitation and applying direct measurement of exposed NaOH solution will be compared and discussed.

A COMPARATIVE STUDY OF PU AND AM MIGRATION CAPABILITY IN CLAY AND SOIL MATRIXES

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Comparative study of americium and plutonium sorption to natural matrixes of different origin containing various amounts of organic substances (from 0.034 to 12.5%) was carried out with the aim of estimation of their migration capability in the environment. Plutonium and americium sorption to three well characterized samples of Triassic clay at trace concentrations was investigated in laboratory experiments as a function of pH and composition of solutions and contact time. The character of Pu and Am bonding to the clay samples was investigated by sequential extraction (SE). Solvent extraction techniques (using TTA, HDEHP, DBM and PMBP), ultrafiltration and alpha spectrometry as well as ICP-MS were employed to characterize the oxidation states of the formed plutonium species. In addition, two Chernobyl soil cores 5 cm in diameter and 7 cm in depth were analyzed on the vertical distribution of Pu and Am, their bonding to soil components as well as on Pu oxidation state distribution in the soil layers.

Experimental data obtained from laboratory and field observations was used in modeling. The kinetic curves were evaluated by fitting the experimental data with six different types of kinetic models derived for the following six control processes: mass transfer (DM), film diffusion (FD), diffusion in the inert layer (ID), diffusion in reacted layer (RLD), chemical reaction (CR) and gel diffusion (GD). The modeling results have indicated that kinetics of sorption of Pu(IV) and Am(III) to natural clay materials is controlled by diffusion in the so-called inert layer of solid phase (ID). The control process of chemical reaction (CR) found for Pu sorption on clay 7 containing carbonate minerals is an exception. The analyses of data obtained from sorption experiments, field observations and speciation of radionuclides have indicated a slightly higher migration potential for Am both in the Chernobyl soil and the natural clay minerals.

Acknowledgements. The research was supported by the Agency for Science, Innovation and Technology of the Republic of Lithuania (contract No. TAP-36/2010) and the Research council of Lithuania (contract No. TAP-54/2010) as well as by the Ministry of Education of the Czech Republic (contract No. MSM 6840770020). The financial support is greatly acknowledged.

UNDERGROUND MIGRATION OF ARTIFICIAL RADIONUCLIDES BEYOND THE DEGELEN MOUNTAINS

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For the territory of the Semipalatinsk test site (STS) the issue of distribution of radioactive products from underground nuclear explosions (UNE) with a flow of groundwater outside the test areas is critically important with respect to Degelen site. Primarily this is due to the peculiarities of the geological structure and hydrogeological conditions of Degelen Mountain, which determined the mechanism of groundwater contamination and conditions of further artificial radionuclides migration in water bodies. It should be noted that the groundwater of the area is marked by the highest value of the content of artificial radionuclides, greatly exceeding the permissible values for drinking water (^{137}Cs up to 700 Bk/l, ^{90}Sr up to 2000 kBq/l, ^{3}H up to 1300 kBq/l and $^{239+240}$Pu up to 110 Bq/l).

Projected estimates made based on current knowledge and data show that in groundwater of Degelen Mountain flowing outside the central zones of UNEs in the absence of abrupt changes there will be slow decrease in the concentration of ^{90}Sr and ^{137}Cs and the weak increase in concentration of $^{239+240}$Pu. Thus, it is possible that in the foreseeable future outside the "Degelen" test area significant changes in radiological environment may occur. To control the possible entry of contaminated groundwater from the sites of nuclear tests into underground water of clean areas, as well as for rapid detection of the initial stage of any adverse trends in the development of radio-ecological situation, the main areas of groundwater withdrawal beyond the Degelen Mountain there is need for radioecological study of groundwater and install observation wells for long-term groundwater monitoring.

This problem has become particularly relevant now in integrated studies for the possibility of transferring part of the STS territory into the economy. It is clear that to fully assess the safety of potential for the transfer of territory it is required not only data on the concentrations of artificial radionuclides in groundwater spreading within STS test grounds, but also forecasts the possibility of entry of contaminated groundwater from the UNE venue in the underground waters of lands to be transferred. This review article presents the results of works carried out by NNC RK divisions in different years to study this problem.

MONITORING RADON EMISSION ANOMALIES AT STROMBOLI ISLAND AS PRECURSORS OF ERUPTIVE EVENTS AND VOLCANICALLY INDUCED EARTHQUAKES

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Geophysical survey is actually largely employed for natural hazard and geological risk mitigation in many different natural context. The real-time monitoring of several geochemical and physical parameters has been applied especially regarding the surveillance of volcanic and seismic area. In this view, monitoring gas emanation from soil is a useful tool to get information about volcano activity, fault surveillance as well as the analysis of the hydrothermal systems.

Radon emission from soil at Stromboli Island have been monitored since 2000 up to present days. We measured great radon anomalies before, during and after the major eruptive events occurred along the last ten years and we noticed a common behaviour: paroxysmal eruptions are preceded by relative minima in radon emission at stations located at the base of the cone, whereas at the summit radon concentration reached peak values (around 20000 Bq/m^3 or higher for the major volcanic events) 10-15 days before eruptions. Radon emissions at or above such high threshold values are proposed to result from the dynamic response of the fracture network due to degassing process associated with magma ascent. We explain the relative minima at the base of the cone with a sort of "self-sealing" effect of the related fractures due to hydrothermal system eventually coupled with atmospheric stack-effect [1]. But radon anomalies were recorded also far from eruptions. Long term measurements have outlined that anomalies are also related to structural setting of the Island, hydrothermal feature in the volcanic field and volcanic earthquakes [2]. Several environmental parameters contribute to the recorded variations of radon activity and multiparametric on-line monitoring network is collecting data of atmospheric pressure, soil humidity, air and soil (1 m depth) temperature together with radon emission [3]. The radon data have been correlated with these environmental parameters in order to investigate their contributions to fluctuations of radon exhalation from soil. We present for the first time the results of the correlated data analysis and we point out that the key variable to investigate the radon transport throughout soils and consequently explain the concentration values measured at 21 surface stations placed on Stromboli flanks along its main faults, is the emanation factor. Emanation factor is related to the capability of radon to move from soil grains to the pores and has been evaluated in the range from 0.002 to 0.02. Emanation factor shows a strict positive correlation with seasonal variation of radon concentration and with soil thermal gradient. Evidence for correlation between emanation factor and soil humidity has been found: data analysis shows soil humidity contributes to short-time (few hours) drastic radon activity increment. From the analysis of our wide set of data we propose a method that may discriminate between changes in radon activity due to "shallow degassing" effects, regarding soil-air process, humidity and atmospheric conditions, and variations related to changes in volcanic activity and/or regarding ascending of magma towards the surface.

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RADIONUCLIDES SPECIES IN SOILS OF THE WATERCOURSE ECOSYSTEM AT DEGELEN MOUNTAIN OF FORMER SEMIPALATINSK TEST SITE

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This paper studies the species of artificial radionuclides ^{137}Cs and ^{90}Sr, ^{241}Am and $^{239+240}$Pu in meadow soil of the watercourses ecosystem at "Degelen" site of the former Semipalatinsk test site. As the main objects of study we selected watercourse ecosystems of tunnels N176 and 177 at Degelen Mountain. To determine the species of radionuclides in the soil we used well-known method of sequential extraction, which is based on selective leaching by various reagents of radionuclides compound groups, differing in the degree of mobility. In ecosystem soils in the area of tunnel number 176 the following main species of ^{137}Cs and ^{90}Sr in soil were identified: water-soluble, exchange, mobile and fixed, in soils, we used for this purpose, respectively, reagents: distilled water, 1 n. solution CH_3COONH_4, 1M and 6M solutions of HCl. Number of radionuclides remaining in the samples of soil after leaching, were classified as tightly bound form. In the soils of the tunnel area N177 we defined the forms associated with soil organic matter extracted by the solution of 1 n. NaOH. The study of the species of transuranic radionuclides ^{241}Am and $^{239+240}$Pu in ecosystems soils around the tunnel N177 was carried out by short plan, highlighting the exchange forms, forms associated with organic matter, mobile and tightly bound forms.

In order to characterise the meadow soils we identified such indicators of physical and chemical properties as the total humus content, granulometric composition, pH of the aqueous extract (actual acidity), total exchangeable bases, the content of readily soluble salts by standard methods in soil science. Based on data obtained it may be noted that the soils are well humus-containing, especially in the centre of the channel, well washed from soluble salts and carbonates. pH of the aqueous suspension is rarely neutral, frequently alkalescent or alkaline. Cation of Ca dominates in the soil - absorption complex. By its mechanical makeup on the site of a detailed survey of the watercourse ecosystem of tunnel N176 the soils are mostly loamy and sandy loam, rarely medium loam, while watercourse area of tunnel N177 among the loose deposits medium and heavy loam dominate (according to Kachinskiy classification).

Conclusions based on the results obtained can be used to assess and forecast the species of the studied radionuclides in the meadow soils of Degelen Mountain as a whole, taking into account the variability of soil characteristics and nature of radioactive contamination.

INSIGHTS ON RADON SURVEYS AT STROMBOLI VOLCANO

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The volcanoes geochemical survey can be very helpful in order to track their activity and, hence, is one of the mostly used for the mitigation of risk in volcanic area. With the aim to better investigate the relationship between volcanic activity and in-soil radon concentration, we deployed in May 2002 a network of 21 sampling sites, at Stromboli island. Periodic measurements were made by means of two different passive methods. Both instruments give integrated measurements of radon activity during their time of exposure. EPERM® electretes have been exposed from 2 to 6 days and allow us to record short (daily/weekly) variations in radon emissions; conversely, LR115 tracketches detectors give us a monthly average ^{222}Rn concentrations.

This wide surveys on a large sector of the island outline the occurrence of diffuse degassing at Stromboli; noteworthy, higher ^{222}Rn emissions are related to the main structural alignment and to the proximity at the crater area. On the large dataset acquired by using EPERM® electrets has been applied a statistical analyses in order to detect the background, threshold and anomalous values on each measurements sites. However, considering the entire network, the activity values ranging (in space and in time) from 0.3 to 30 kBq/m^3. Track-etches acquired data has been used to construct a timeseries on the 2002-2007 lapse of time. Results confirm the relation between volcanic activity and in-soil ^{222}Rn activity; particularly the higher concentrations was recorded during the two effusive events interesting Stromboli volcano (Dec 28, 2002 – Jul 21, 2003 and Feb 27 – Apr 2, 2007, respectively). During the considered period a relation between seismic events occurring in the Southern Tyrrhenian area and radon emissions have been observed.

Starting from April 2007, the ^{222}Rn measurements at Stromboli are acquired in real-time thanks to the installation of two multi-parametric fully-automated stations capable to acquire ^{222}Rn concentration, soil temperature and atmospheric pressure values each 15 minutes. Data are instantaneously transferred, stored and visualized in a PC (that can be remotely checked) placed at COA of Stromboli. The automated dataset outline the influence of environmental parameters (e.g. soil temperature and atmospheric pressure) on the capability of ^{222}Rn to move from depth to the surface. These preliminary results are very useful in order to better understand the radon transport processes trough the soil and, finally, to recognize the different causes able to promote variations in radon emissions in volcanic area.

ASSESSMENT OF GROUNDWATER CONTAMINATION WITH TRITIUM BY ITS CONTENT IN THE VEGETATION COVER AT THE TERRITORY OF FORMER SEMIPALATINSK TEST SITE

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One of the problems of the former Semipalatinsk test site is the groundwater areas contaminated with radionuclide ^{3}H. To date, the concentration of ^{3}H in the groundwater outside the Degelen Mountain (former "Degelen" site) is tens of kilobecquerels per kilogram, and at the particular sectors of Shagan River the concentration reaches hundreds of kilobecquerels per kilogram. Particular importance of the situation is endangered by including the latter in a single hydrodynamic system; in this regard the problem is able to acquire a regional character.

Due to the priority of this issue there is a need to develop a method that would allow assessing the content of ^{3}H in the ground water without expensive drilling. In this work, as indicators of ^{3}H content in the groundwater we used plants. Vegetation was studied by separate methods of geobotanical describe with the allocation of major types of vegetation and plant species composition. The objects of study, selection of which was based on their classification in relation to water, were the representatives of hygrophytes, mesophyte, xerophyte, as well as a special group - phreatophytes with deeply penetrating roots reaching the ground water. The test samples of herbaceous plants were aboveground parts of shrubs and trees - current annual increment, the content of ^{3}H was determined in the free water of plants. For a comparative analysis of the ^{3}H content in the studied plants with its contents in groundwater in some research sites hydrogeological wells were drilled from which sampling of groundwater was made. Measuring the specific activity of radionuclide ^{3}H was conducted in prepared samples by the method of liquid scintillation spectrometry for TRI-CARB 2900 TR liquid scintillation spectrometer.

According to the results of the research, there was determined dependence of the concentration of ^{3}H in the plants on its content in groundwater. We revealed the most suitable in terms of accumulative bioindication, plants: reeds (Phragmites australis), which is hygrophytes and phreatophytes - poplar (Populus nigra), willow (Salix triandra), cheegrass (Achnaterum splendens), licorice (Glycyrrhiza uralensis) and salt tree (Halimodendron halodendron). The assessment was done for groundwater contamination with ^{3}H flowing beyond Degelen Mountain by its content in the vegetation cover.

OPTIMISATION OF SR-90/SR-89 MEASUREMENTS

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In the case of an emission of radionuclides from a nuclear installation, ^{90}Sr appears with ^{89}Sr, both beta emitters. At the time of fission the ratio of ^{89}Sr/^{90}Sr activities is around 150.

For their analysis in any sample, as ^{89}Sr and ^{90}Sr are isotopes of the same element, they are isolated together in the radiochemical extraction process of Sr and ^{90}Y starts growing from ^{90}Sr, being its half life 2.8 days. Each one of these three radionuclides interferes in the measurement process of the others. Making two different measurements of the sample, following the radiochemical purification process of Sr, at two different times, t_1 and t_2, allows the calculation of the ^{90}Sr activity in the sample, as well as ^{89}Sr activity.

One of the main points to take into account in this method is the choice of the times, t_1 and t_2, at which the measurements will be done. The choice depends on the required detection limits and uncertainties. That is, on the desired quality of the results to be obtained.

In this work formulae to calculate the ^{89}Sr and ^{90}Sr activities in the sample, their uncertainties, decision thresholds and detection limits are provided as a function of t_1 and t_2. Establishing t1, the time interval between measurements and the initial activities of ^{89}Sr and ^{90}Sr as independents variables, an analysis of the behaviour of the detection limits and the relative uncertainties has been carried out. The analysis has been done for radiation counting carried out with a gas flow proportional counter. And different conclusions have been derived:

- the detection limit as well as the relative uncertainty, for both radionuclides increase with t1 and decreases with the time interval between measurements;
- the relative uncertainty from each radionuclide increases with the activity concentration of the other one and decreases with its own activity concentration;
- the detection limit from each radionuclide increases with the activity concentration of the other one and does not depend on its own activity concentration.

RADIOCHEMICAL ANALYSIS OF WATERS AND MUD OF EUGANEAN THERMAL DISTRICT (PADUA)

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The area around the Euganean Hills (North-East Italy) is concerned with thermal phenomena known and used for therapeutic purposes since ancient times.

The thermal waters collected in this area have taken a natural radionuclides content due to the leaching of hot and permeable deep rocks, with which they come in contact, before their rising to the surface. During the maturation process of mud, used for treatment purposes, the contact of thermal waters with mud results in an enrichment phenomenon for some radionuclides.

In this work the first radiochemical analysis extended to all Euganean Thermal District is reported. In particular, chemical analyses of mud, as well as radiochemical analyses of both mud and waters were performed; also, the enrichment of the radioisotopes in mud used for treatments was established.

The results show that ^{226}Ra content in mud, during maturation process, presents an enrichment even of two orders of magnitude with respect to the value found in the unprocessed mud.

Furthermore, in the same thermal waters, high concentrations of unsupported 222Rn have been found, which have shown to be not negligible both for people under treatment and particularly for spa workers.

FORMATION OF TRITIUM CONTAMINATION OF AIR BASIN AT THE SITES OF UNDERGROUND NUCLEAR EXPLOSIONS AT THE FORMER SEMIPALATINSK TEST SITE AREA

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The objectives is assessing the level and distribution of tritium in the atmospheric air and study the formation of tritium contamination of the air medium on the sites of underground nuclear explosions at the Semipalatinsk test site (STS) within the Degelen Mountain.

During the period of testing from 1945 to 1962 on territory of Degelen Mountain in horizontal mines - the tunnels 209 underground nuclear explosions were produced. Many tunnels have

seasonal water seepage in the form of streams, through which there is removal of tritium from the UNE venues to the surface. Concentration of tritium in streams is up to n*105 Bq/kg of order of magnitude.

Investigation of the level and distribution of tritium in the atmospheric air was carried by the example of ecosystem tunnels N176 and N177 with water seepage located in Degelen Mountain.

The main feature of the selected sites is the presence of tunnels with water seepage in the form of an open watercourse flowing out to the surface at the tunnel portal. The length of the watercourse is about 400-600 m, with a gradual drying out as the distance from the portal. The average specific activity of tritium in water is 350 Bq/kg and 550 Bq/kg at tunnels N176 and N177, respectively.

As objects of study, we chose water, vegetation, soil moisture and tunnel air, as the most probable sources of contamination of the air with tritium in the area.

Investigation of the tritium concentration level in the atmosphere was carried out through sampling of water vapor, and further liquid scintillation beta-spectrometric analysis. Sampling of water vapor from atmospheric and tunnel air, soil moisture was carried out by cryogenic freezing. The selection of plants was based on the study of vegetation by individual methods of geobotanical description with the allocation of major vegetation types, the definition of a projective cover and species composition of plants and was based on their classification in relation to moisture. The content of tritium was determined in the free water of plants.

Investigation of the level and distribution of tritium in air in the vicinity of the tunnels with water seepage was carried out by assessing the concentration of tritium in the air along the watercourse of tunnel brook, and on profiles located in a transverse direction relative to the channel, with gradual leaving from it.

During the study, an overall picture of distribution was seen which is typical for the selected ecosystems that represents the isosurface which has a dome shape cross section. The highest concentrations of tritium in the atmosphere are typical for the areas where tunnel streams are located with high concentrations of tritium in water. The concentration of tritium in the atmosphere is significantly reduced with increasing the distance, both along the channel of the tunnel creek and aside from it.

When studying the basic mechanisms and distribution of tritium in the air ecosystems the following mechanisms were identified and investigated:

- distribution of tritium in the system water - atmospheric air;
- distribution of tritium in the system tunnel air - atmospheric air;
- distribution of tritium in the system soil air - atmospheric air;
- distribution of tritium in the system plant - atmospheric air.

Investigation of the concentration levels of tritium in air of Degelen Mountain in locations of tunnels with water seepage showed that the contamination of the atmosphere with tritium in the estuarine areas of the tunnels was formed by a few major sources. They are soil air in places of shallow groundwater, surface water and vegetation. The main areas that have been contaminated

with tritium are located along the course of streams, by the removal of tritium with watercourses from tunnel cavity. Tritium concentration that was recorded in air on estuarine areas of the tunnels in some cases, reaches more than 1000 Bq/m^3 that does not exceed, but is close to the limit of allowable annual average volume activity in the air for the population, which equals to 1900 Bq/m^3.

The results of this work will allow predictions of air contamination with tritium at relatively contaminated areas at the nuclear tests sites, as well as in activities related to nuclear industry.

STUDY OF RATIO OF PU-241 AND AM-241 ACTIVITIES IN SOIL OF THE MAIN TEST GROUNDS AT STS

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This research was conducted to study the ratio of ^{241}Pu/^{241}Am in the soil at the main test grounds of the former Semipalatinsk test site (STS) and to identify the areas where it has constant nature. This is of great importance during radio-ecological studies, because it becomes possible to assess the concentration of ^{241}Pu by the results of the gamma-spectrometric analysis of ^{241}Am, which leads to a significant reduction in labour costs, due to the fact that the instrumental determination of ^{241}Am is much easier and cheaper than the radiochemical determination of ^{241}Pu.

In order to determine the activity of ^{241}Am and ^{241}Pu we took surface soil samples from the main test grounds of the former STS (Degelen, Atomic Lake, Experimental field, radiological weapon test ground).

Measurements of ^{241}Am activity were done by instrumental gamma-spectrometric method employing a planar (BE 2020) germanium detector from «CANBERRA» company by three parallel samples weighing 200 g, prepared from one sample.

To determine ^{241}Pu concentration, there was developed and tested a method of liquid scintillation beta-spectrometric determination of ^{241}Pu activity. The detection limit was 20 Bq/kg.

The article presents the results of ^{241}Pu and ^{241}Am activity measurements, as well as their relation to soil of main test grounds of the former STS. These ratios range from 1.3 to 18.9. For local areas the ratio is constant, there are exceptions only for "Radiological weapon test ground" and "Degelen" site.

Measurements of ^{241}Pu activity were performed by liquid-scintillation using a liquid scintillation beta-spectrometer TRI-CARB 2900 with preliminary radiochemical separation of plutonium isotopes.

PECULIARITIES OF RADIONUCLIDE CONTAMINATION OF SHAGAN RIVER

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Shallow Shagan River with the feeder Ashisu is the main river artery in the territory of the former Semipalatinsk test site. It is a left-bank tributary of the Irtysh River, flows along the eastern boundary of the test site.

On January 15, 1965 at the confluence of the rivers Shagan and Ashisu at a depth of 178 m thermonuclear explosion with ejection of the soil was produced. The blast created a crater with diameter along the crest of 408 m, 100 m deep and a volume of 10 million m^3. After filling the crater water reservoir was created that was named "Atomic" lake. From the earliest days this object has been subject to strict radiation control. For example, it is known that the level of gamma radiation in the vicinity of the crater by the end of the first day was up to 0.3 Sv/h, in 10 days - dropped to 0.01 Sv/h, and currently at 20-30 mSv/h , which is 2 orders of magnitude higher than the natural background radiation. However, even at distances of 1-2 km from the crest of the crater level of gamma radiation decreases to background values. The same pattern was observed with the content of radionuclides ^{241}Am, $^{239+240}Pu$, ^{137}Cs, ^{90}Sr, ^{152}Eu, ^{154}Eu in the soil, although in the zone of soil pile their concentrations are thousands of Bq/kg. Artificial radionuclides concentrations in the water at the outlet of the «atomic» lake now are below the permissible levels defined in Radiation Safety Standards of the Republic of Kazakhstan and are not dangerous.

According to the works done it was found that at the interval of 4 to 5 km from the "Atomic" lake there is discharge of groundwater contaminated with tritium into the surface watercourse of Shagan River. The source of contamination, apparently, is the groundwater migrating from the warfare wells of "Balapan" site where in the period from 1961 to 1989 131 underground high power nuclear explosions were conducted (up to 150 kilotons of TNT equivalent) in vertical excavations - boreholes. The specific activity of ^{3}H in water at this site reaches 680 kBq/kg. Such water is actually a liquid radioactive waste. This site is a source of secondary contamination of ecosystem components with tritium, such as air, plants and livestock products.

Currently, the Institute of Radiation Safety and Ecology NNC has initiated a program to transfer the lands of the former test site that are not affected by nuclear testing into commercial use. The discovered fact of that significant radioactive contamination of the Shagan River stretch dictates holding a range of other activities aimed at the removal of potentially hazardous lands from commercial use.

At the present day studies are being performed on nature of the areal tritium distribution in the groundwater of the territory adjacent to the Shagan River.

RAPID MEASUREMENT OF PU-241 ACTIVITY AT ENVIRONMENTAL LEVELS USING LOW-LEVEL LIQUID SCINTILLATION ANALYSIS

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A straightforward and rapid method has been developed for the determination of 241Pu activities. Pu is chemically separated from the sample, purified and electrodeposited to produce a source for alpha spectrometric determination of ^{238}Pu and ^{239,240}Pu. Pu is stripped from the disc with concentrated nitric acid and extracted into TOPO/toluene. The organic extract is then mixed directly with commercial liquid scintillant without any further preparation and the sample counted on a Wallac 1220 Quantulus liquid scintillation counter. ^{241}Pu activity is estimated via the ^{242}Pu yield monitor acquired by alpha spectrometry measurement. Experimental results for the performance testing of a low-level liquid scintillation spectrometer (Quantulus 1220) and the data for the evaluation of the method using standard reference materials are presented.

RADIOCARBON CONSTRAINTS FOR SOIL CARBON ACCUMULATION AND CARBON RELEASE OF BOREAL FORESTS AND TUNDRA ECOSYSTEM IN ALASKA

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High-latitude soil organic carbon (SOC) stocks are of particular interest because warming is expected to be greatest, thawing permafrost and induce acceleration of SOC decomposition at high latitudes, raising questions about the fate of SOC. However, merely knowing the size of the reservoir of carbon stored soils in sufficient for predicting its potential to influence atmospheric CO_2 concentrations. We must know something about soil carbon dynamics in high-latitudes. Soil and soil CO_2 above the permafrost were collected along the Dalton Highway, between Fairbanks and Deadhorse near the Arctic coast. The observation area extends from Tundra in the Arctic coast, mountain area in the Brooksrange, then boreal forests in the south of Brooksrange. We measure C contents of SOC and the radiocarbon age of SOC and ecosystem respiration. Thick moss and detrital layers were found in poorly drained soils. According to ^{14}C data, the thickness of the recent detritus accumulated after 1960s' were from 10 cm to 14 cm in boreal forests and from 8 cm to 13 cm in Tundra ecosystem. Bomb ^{14}C contents and TOC down profiles suggested that boreal forests had large amount of SOC above permafrost and high accumulation rates which corresponded to 6.6 – 8.2 kg m^{-2} for past 60 years. We also discuss origin of soil respired CO_2 based on ^{14}C in this conference.

RADIOACTIVITY IN GROUNDWATER FROM THE SOUTH-EASTERN UNITED ARAB EMIRATES

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Groundwater composes a vital resource in arid regions, including the UAE, where identification of its quality and origin is indispensable. Two main (shallow and deep) groundwater sources are commonly recognized in the southeastern UAE. The origin of the shallow sources is related to surface recharge, whereas the source of the deep groundwater is rather obscure. Groundwater was sampled from wells (deep source) drilled in fractured carbonate rocks along the foothill of about 1200 m absl high mountain (Jabel Hafit) and wells (shallow source) drilled in clastic sediments from a nearby plain (Al Jawa Plain). Water from the mountain foothill is rather warm (thermal water) and commonly used for recreational activities, artificial ponds and watering. Groundwater of the plain region is commonly used for agriculture and household. A combination of chemical composition and radioactivity were used to characterize the water types. Relatively high temperature (up to 50 °C) and high TDS (up to 7000 mg/L) associate the thermal water compared to the groundwater of the plain (T <35oC and TDS <350 mg/L). The thermal water also shows relatively high concentration of chloride and sodium as well as bicarbonate and sulphate. Results of the radioactivity measurements indicate wide difference between the two water types. The thermal groundwater is characterized by 2-3 orders of magnitude higher concentration of ^{222}Rn and ^{226}Ra than the groundwater from the plain region. Similarly is the range of variability for gross alpha, but the gross gamma activity indicates only 1 order of magnitude difference between the two water types. The high radioactivity, temperature and salinity of the thermal groundwater suggest transport through radioactively-richer and likely deeper aquifers than the groundwater of the plain. The thermal water may reflect signature of deep basinal fluids along the southeastern part of the Oman ophiolite zone.

I-129 ENVIRONMENTAL POLLUTION IN THE BALTIC SEA

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Concern about discharge and entrapment of pollutants in the Baltic Sea has been going on for many years and governmental agencies and scientists are putting a lot of effort to delineate the problems and find remedial measures. In some cases, the pollutant may not pose, at present, a direct environmental threat, but evaluation of its concentration and distribution paths in the Baltic Sea are necessary in order to avoid unpredicted environmental problem in the future. An example of such situation is given by the radioactive isotope iodine-129. Despite reports showing 1000-10000 higher than natural values increase of the isotope concentrations in the Baltic Sea, investigations of the isotope spatial and temporal variability are sparse. The relatively long half-life (≈16 million years) may reduce the radioactivity dose effect in the environment. Nevertheless, caution about radioactive pollution and detailed studies of the isotope load in the Baltic Sea are indispensable. We here present results from a regional survey of the isotope variability in the Baltic Sea water during 2007 and 2008. The data reveal large differences in ^{129}I concentration and suggest that over time of about 50 years there has been an increase in the basins of Kattegat and Baltic Proper whereas the concentration remained rather constant or partly decreased in the Skagerrak Basin. Standing crop (inventory) of ^{129}I in the water of the basins sums up to a total of 30-40 kg, residing differently in the water layers. Model calculation indicates that the major source of the isotope is seawater inflow from the North Sea, but some input is also supplied from sediment releases particularly in the relatively anoxic deep parts of the Baltic Sea. The sediment release can add more ^{129}I to the Baltic Sea water in a future globally warmer climate. Presently there is no concise on the ^{129}I cycling in the different compartments (water-biota-sediment) of the Baltic Sea, which is crucial to the estimate of present and future radioactivity hazards resulting from ^{129}I intake and effects on the human body.

ENVIRONMENTAL IMPLICATIONS OF ANTHROPOGENIC I-129 IN THE NORDIC SEAS

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Large amounts of the radioactive iodine-129 isotope have been accumulating and circulating in the Nordic Seas since the beginning of the nuclear era. Although the anthropogenic input of the isotope may not produce radioactive ecological hazards, information about concentration and inventory is vital for evaluation of existing situation and application to identification of water masses and circulation in the region. We present here data about distribution of ^{129}I in several water depth profiles (ranging from the surface to about 900 m) collected in the Nordic Seas during the period of May-June 2002. In general, the results indicate that concentrations in the top 100 m of the Nordic Seas are 1,000-50,000 times more than the natural level (~4x105 atoms ^{129}I/L) and have usually a downward gradient with depth, reaching at 900 m 1,000-3,000 times the natural level. The North Atlantic inflows away from the European coastline are even lower in ^{129}I, exhibiting only 50-150 times of natural level. In addition to the wide range of variability in the isotope concentration depth wise, there is also a quite distinctive signature of water masses and their circulation pattern in the Nordic seas. Before entering the Barents Sea, the ^{129}I-rich water masses spilt into two branches, one diverts towards the Barents Sea and other one follows with the West Spitzbergen Current towards the Fram Strait and into the Arctic Ocean. Although most of anthropogenic ^{129}I resides in the Arctic Ocean, some of it together with that recirculated with return water masses from the West Spitzbergen Current enter into the East Greenland Current. This ^{129}I further travels across the Denmark Strait and increases ^{129}I concentration in the water masses. The anthropogenic ^{129}I contamination provides clear signature of water outflows from the Denmark Strait that further continues into the North Atlantic. Our data also support another source of ^{129}I back contamination into the North Atlantic through deep outflows at the Faeroe Bank Channel.

TECTONIC AND GEOLOGICAL CONTROLS ON SOIL GAS RADON IN SEISMICALLY ACTIVE AREAS OF DHARAMSHALA AND CHAMBA REGION OF HIMACHAL PRADESH, INDIA

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Radon is a radioactive gas which makes the primary contribution to the natural radiation to which people are exposed. Considering its carcinogenic health effects, great importance is attributed to the determination of radon concentration levels in water, indoor air and soil gas. In this present investigation, wide range of soil gas Radon measurements in different formations were made in Chamba and Dharamshala, Himachal Pradesh, India in order to establish possible correlation between soil gas Radon concentration and geology/active tectonics of study region. It has been observed that Radon emission is strongly influenced by deep seated thrusts and various lithological units present in the study area.

CA-41, C-14 AND BE-10 CONCENTRATIONS IN CORAL $CaCO_3$ FROM THE NUCLEAR TEST SITE BIKINI ATOLL DETERMINED WITH LOW ENERGY AMS

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Measurements of the activation of materials exposed to nuclear bomb explosions are widely used to reconstruct the neutron flux (DS02, 2005). Especially in biological material the concentrations of radioisotopes like ^{41}Ca can be used for retrospective dosimetry [1, 2].

At the low-energy AMS facilities of ETH Zurich a variety of long-lived radioisotopes can be studied, e.g. ^{10}Be [3], ^{14}C [4] and ^{41}Ca [5]. In several sediment samples from the Bikini atoll the ^{41}Ca/^{40}Ca and ^{14}C/^{12}C ratios and also the ^{10}Be concentration have been measured. Elevated values have been found for all isotopes in a highly contaminated sample from the crater of the high yield nuclear explosion Castle Bravo (1954). The results are compared with existing Plutonium isotope ratio and activity concentration data of the same samples [6].

In the special assembly of a high yield nuclear explosion on top of a coral island the available targets for the production of ^{41}Ca, ^{14}C and ^{10}Be are the coral $CaCO_3$ (possibly containing also other target nuclides) and H_2O. Predominantly the radionuclides initially produced in the $CaCO_3$ molecule are expected to be at least partially preserved in the present-day sediment, which consists almost exclusively of coarse grained $CaCO_3$ sand. The aim of this study is to test the

applicability of the coral $CaCO_3$ as a biogenic neutron flux dosimeter for this case. In a first step the measured values of the radionuclides are compared to the expected concentrations from the cross sections for their respective production from a pure $CaCO_3$ target. The results indicate that more complex scenarios than a simple $CaCO_3$ irradiation have to be discussed, e.g. input from other production processes, from further targets in the coral, from the following bomb tests at the same site or from subsequent bioproductivity.

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INDOOR RADON CONCENTRATION MEASUREMENTS USING ELECTRET ION CHAMBER MONITORS

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Radon has been receiving considered global attention because of the radiation-induced public health hazards. To address this concern, indoor radon concentration measurements were performed in the Metropolitan Region of Belo Horizonte, Brazil by using the E-PERM® Electret Ion Chamber method. It also presents a preliminary characterization of the radioactivity in the main radon sources: soil and building construction material. Most part of the inhabitants of this area lives in a granitic bedrock region, which has higher uranium contents than the average value for the earth crustal and consequently, radon potential production. The results show a general log-

normal distribution for the indoor radon concentration, with an average value of 108 Bq m^{-3}, standard deviation of 170 Bq m^{-3}, median of 70 Bq m^{-3} and geometric mean equal to 76 Bq m^{-3}. About 15% of these results are over the United States Environmental Protection Agency (U.S. EPA) action level, which is 148 Bq m^{-3}. The equilibrium factor (F) was determined in 14 typical dwellings by using a solid state alpha spectroscope, the DOSEman PRO (Sarad), for radon progeny and simultaneously with a continuous detector AlphaGUARD PQ200PRO (Saphymo GmbH), in passive mode, for radon gas. It was found an average equilibrium factor of the 0.3. Measurements of soil gas radon concentration were carried out with AlphaGUARD PQ200PRO (Saphymo GmbH), in flow mode, and the average was found to be 34 kBq m^{-3}. The radionuclide activity concentrations in construction material samples were measured through Neutron Activation Analysis and through gamma-ray spectrometry (HPGe detector). It was found that all the analyzed construction material samples, except gypsum, presented significant activity for the Unatural, ^{232}Th, ^{214}Bi (^{226}Ra), ^{212}Pb (^{224}Ra). Based on indoor results, the approximate average of the effective dose to RMBH inhabitants was 2.0 mSv, according to the calculation model presented in the UNSCEAR 2000 report.

RADIOACTIVITY OF DUMPS IN MINING AREAS OF THE UPPER SILESIAN COAL BASIN IN POLAND

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Underground coal mining is associated with large quantities of gangue. In the past, the majority of gangue was not utilized but was placed in the vicinity of coal mines forming cone-shaped dumps. Some of them contained even millions of tones of rocks. Nowadays, environmental precautions extort larger utilization of any kind of waste materials, for example in road construction, civil engineering or as stowing in underground abandoned workings. Any economical utilization of waste materials requires former studies assuring their lack of hazardous influence on natural environment and humans, including radioactivity. Examination of the radioactivity of wastes is quite important due to the fact that they may be used in production of building materials used in residential constructions.

The paper presents results of a radiological survey carried out in several dumps located in the Upper Silesian Coal Basin in the south of Poland. Measurements of samples were carried out with the use of a gamma spectrometer made of a semi-conductor detector Ge(Li), Camac system electronics and TUKAN 4096 channel analyzer. The analyses of spectra were performed by means of GANNAS program.

Activity concentrations results of radioactive elements of uranium and thorium decay chains will be discussed.

RADIOACTIVE TRACERS FOR LONG RANGE TRANSPORT OF BIOMASS BURNING AEROSOLS

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Biomass burning caused by anthropogenic activity such as agriculture practices or naturally occurring forest fires is a frequent phenomenon causing global environmental concern for many reasons. Release of certain radioactive or other hazardous compounds from forest fires occurring over contaminated land is one such issue for concern. The physicochemical processing occurring on smoke particles released in the atmosphere during long range transport is also another topic of interest.

This work presents first results from atmospheric measurements conducted during August 2010 in the Demokritos ERL sampling site for ambient TSP aerosol collected by a High Volume Sampler and analyzed for total β radioactivity and γ spectrometry. Filters were analyzed after a period of 4 days past sampling in order to allow decay of short lived Radon and Thorn daughters. Parallel measurements of aerosol physicochemical properties at the GAW DEM station were also employed.

It was observed that enhanced levels for total beta radioactivity were observed in the period of 12-18 of August compared to the remaining period. An average value of 2.0 ± 0.3 mBq/m^3 was measured over the first period compared to 1.0 ± 0.2 mBq/m^3 found for the rest of the sampling period. The latter is found equivalent to the background levels observed at the site during the summer months. It was also observed that during the enhancement in radioactivity organic and elemental carbon levels were also enhanced above the mean value of long term observations at the site. Especially for organic carbon a higher mean value of 4.4 ± 1.1 μg/m^3 was observed during the "episode" period compared to the rest of the time when 2.4 4 ± 0.7 μg/m^3 was measured.

Air mass back trajectory analysis indicated that the origin of the air mass crossing Athens during the 12-18 of August was the European Russian central plains where extensive forest fires were raging. The enhanced organic carbon values is a strong sugnal for forest fires. The enhanced radioactivity is initially attributed to higher amounts of natural radioactive isotopes like ^{210}Po [1], ^{40}K and ^{7}Be normally found in vegetation and released in the smoke.

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ANALYSIS OF THE REPRESENTATIVENESS OF THE TAKASAKI, GUNMA (RN38) IMS STATION USING INCREASING RESOLUTION METEOROLOGICAL MODELLING

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Within the Comprehensive Nuclear Test Ban Treaty Organisation (CTBTO), receptor-oriented atmospheric transport modelling (ATM) is used to assess the origin of air masses sampled at the International Monitoring System (IMS) stations. Typically, the ATM is driven by global meteorological models, such as the ECMWF (European Centre for Medium-Range Weather Forecasting), at a coarse horizontal resolution of 1 degree. However, in topographically highly structured areas, where some of the IMS stations are located, this resolution may not suffice. In this context, the Japanese RN38 station has been selected as one of the target stations included in a research project funded by a voluntary contribution of the State Signatory Spain to the CTBTO Provisional Technical Secretariat. This study aims at evaluating how the use of a high-resolution, nested meteorological model in the ATM calculations would influence on the obtained Source-Receptor sensitivity (SRS) fields and how this would affect the representativity of the selected stations. In order to obtain the better resolved meteorological fields, the well-known limited-area PSU/NCAR mesoscale model (known as MM5) is used in combination with the Lagrangian particle model FLEXPART v6.2 (one version ahead the one

currently used by the CTBTO), to compute the SRS fields and compare them with the product of the ATM ECMWF-based CTBTO calculations. Differences are evaluated under various scenarios.

INTEGRATED APPROACH FOR THE OPTIMIZATION OF Γ SPECTROSCOPY METHODOLOGY FOR ENVIRONMENTAL RADIOACTIVITY

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The study of environmental radioactivity [1], through the determination of radionuclide components present in soils and rocks gives us the possibility to:

- identify areas contaminated by artificial radionuclides;
- study the distribution of NORM (Naturally Occurring Radioactive Material) and TENORM (Technologically-Enhanced Naturally Occurring Radioactive Material);

- construct maps of U, Th and K distributions that on the basis of the geochemical diversity allow to characterize the origin of local soil and assess surface discontinuity connected to the geological origin, the use and the management of soil.

The ability to obtain a sufficient amount of information to construct reliable maps of distribution is based on the availability of a large number of data, and whose collection takes advantages from the use of “in situ” gamma spectrometry.

The methodology described in this work is based on “in situ” measurements using a NaI detector, that allows to collect quickly a lot of data [2, 3].

In situ γ spectrometry has been supported by new and older calibration techniques (Monte Carlo Method - Point sources - Calibration Pads) and it has been combined with measurements in laboratory using HPGe detectors and with XRF, both for independent analytical check and for the characterization of secondary standards.

This integrated approach provide a valuable methodology of great environmental interest and finds a wide range of applications.

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SESSION III

ATMOSPHERIC RADIOACTIVITY MONITORING IN SLOVAKIA

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Several radionuclides (^{14}C, ^{7}Be, ^{40}K, ^{137}Cs, ^{210}Pb and ^{222}Rn) were studied during the last two decades in the Slovakia air with the aim to better understanding processes taking place in the atmosphere, a quantification of the atmospheric contamination and its trend, as well as an evaluation of possible health risks. ^{14}C content in the atmosphere was investigated in two localities, in Bratislava and Zlkovce. The samples taken in Bratislava station (city with 0.5 million inhabitants) correspond to highly industrialized region. The second station Zlkovce is situated approximately 60 km NE from Bratislava in a flat agricultural area. A high variability in ^{14}C concentration in the atmospheric CO_2 was observed at these stations until 1993. In this period the annual mean values of delta ^{14}C in heavily polluted atmosphere of Bratislava were about 50 % lower, and at Zlkovce about 20 % lower, compared to delta ^{14}C in European background air. Since 1994 the annual mean of delta ^{14}C has been at both sites close to each other. This behaviour could be explained by the decrease of the fossil fuel CO_2 emissions in Slovakia after 1990, and their stabilization after 1994.

^{7}Be, ^{40}K, ^{137}Cs and ^{210}Pb in the ground level atmosphere of Bratislava were collected on aerosol nitro-cellulose filters. The concentrations of ^{210}Pb and ^{7}Be ranged from 0.22 to 2.37 mBq m^{-3} with the mean value of 0.73±0.03 mBq m^{-3}, and from 0.23 to 5.1 mBq m^{-3} with the mean value of 2.49±0.06 mBq m^{-3}, respectively. The aerosol component of the ground level atmosphere in Bratislava showed typical values of activity concentrations also for ^{137}Cs and ^{40}K, as expected for the Central Europe.

The ^{222}Rn activity concentration was continuously monitored in the surface air since 1991 using a large volume scintillation chamber. In the period 1991 – 2009 the average annual activity varied from 4.1 to 7.2 Bq m^{-3} with arithmetic mean of 5.2 Bq m^{-3}. The average daily courses of the radon activity for individual months have a form of variations with maximum in the morning hours and minimum in the afternoon. The highest amplitude of the daily variations was found out in August (2.7 Bq m^{-3}) and the lowest in December (0.7 Bq m^{-3}). The average annual radon course calculated on the basis of all the measured data reaches minimum in April and maximum in October, seasonal variations ranged from 3.7 to 6.6 Bq m^{-3}. The annual radon courses differ from each other for various years and periods of the day. These differences can be explained by various levels of stability of the surface layer of the atmosphere. The results of the radon investigation have contributed to better understanding of the processes in the surface layer of the atmosphere under variable meteorological conditions, and for more precise estimation of the public radiation dose due to inhalation of ^{222}Rn and its decay products.

RADIOCARBON DATING FOR PALEOENVIROMENTAL PEAT ARCHIVE: THE CASE STUDY OF PLANT CELLULOSE FROM PEAT CORE REACHED TO 15KA IN NORTHERN JAPAN

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Peat sediment is one of the most important archives to reconstruct a past climate. From previous study, we found that stable carbon isotope ratio ($\delta^{13}C$) of peat cellulose is used as indicators of East Asian monsoon variability since the last deglaciaion including abrupt climate change (Shinozaki et al., in submission). The $\delta^{13}C$ values recorded variability of rainfall amount related with Northern hemispheric climate change including Asian monsoon. The amount of rainfall seems to be negatively correlated with the plant $\delta^{13}C$ values. Thus, it is crucial to establish correct age model with decadal to centennial time resolution. However, peat exists in forms of matrixes of organic matter such as intact plant and plant debris with soil mineral. In this study, we present radiocarbon dates of intact plant (Sphagnum), plant cellulose, and bulk organic matter from same horizons of peat core to investigate adequate dating candidates. Results of radiocarbon dates from plant cellulose were compared with those of bulk organic matter and intact plant (sphagnum). In addition, we tried three cellulose extraction methods to decide the most suitable one; procedure (I) extended Acid-Alkali-Acid procedure, (II) removed lipids using solvent processing and (III) extended cuprammonium solution (CUAM) procedure. To check their purity, we measured each recovery rate (%), TOC (%), TON (%), $\delta^{13}C$ (‰) and NMR analysis. From these measurements, we have concluded that procedure (I) is the most pure and efficient cellulose extraction method. Additionally, we measured ^{14}C content of cellulose, extracted with procedure (1), bulk sediment and sphagnum of same layers. As a result, ^{14}C absolute age of sphagnum are older than bulk sediments and cellulose. Sphagnum does not have roots and grows in an upward direction from the apex. There is a little possibility that the sphagnum influence to the underlying peat. Therefore, when the peat sediment consists of mainly sphagnum, it is desired to pick up sphagnum for ^{14}C dating. Meanwhile, the ^{14}C of cellulose have large age difference to that of sphagnum by 500 yrs, compared to that of bulk sediments. In the case that the sphagnum cannot have obtained sufficient amount or almost decomposed, bulk organic matter is better than cellulose for ^{14}C dating.

A SENSITIVE AND ACCURATE METHOD FOR SIMULTANEOUS DETERMINATION OF PB-210 AND PB-212 IN DRINKING WATER SAMPLES

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A sensitive and accurate method for determination of ^{210}Pb and ^{212}Pb in drinking water samples was developed. In the method Pb was pre-concentrated as hydroxides, separated from alkaline earth elements as PbS precipitate, purified by an anion exchange resin chromatography column, precipitated as $PbSO_4$ for source preparation and counted by a low background β-counter. The procedure was checked with a reference material supplied by the IAEA, and the obtained data were in good agreement with the recommended values, showing the recommended procedure can provide reliable results. The minimum detectable activity of the method was 0.039 mBq L^{-1} for ^{210}Pb and 0.033 mBq L^{-1} for ^{212}Pb if a 48 litre of water sample was analysed. Seventeen drinking water samples were analysed with a Pb recovery of 88.8±5.5%, and the typical activity concentrations were in the range of 0.191-15.1 mBq L^{-1} for ^{210}Pb and of 1.12-5.77 mBq L^{-1} for ^{212}Pb. The estimated committed effective doses to the adult member of public in Italy due to intake of ^{210}Pb and ^{212}Pb in drinking water were in the range of 0.096-7.59 μSv yr^{-1} and 0.0049-0.0253 μSv yr^{-1}, respectively.

MEASUREMENT OF CS-137 IN SOIL IN KOREA BY USING A LOW-LEVEL BACKGROUND GAMMA-RAY SPECTROMETER

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^{137}Cs in the soils collected from Korea from 2006 to 2008 was measured by using the low-level background gamma-ray spectrometer which was designed and was developed by KRISS (Korea Research Institute of Standards and Science). The objectives of this study are to evaluate the new developed low-level background gamma-ray spectrometer and consequently to provide information on the horizontal and vertical distribution of ^{137}Cs in the soil in Korea.

^{137}Cs concentrations in surface soil varied from 12.8 ± 0.9 to 108 ± 4 Bq kg^{-1} and the vertical profiles of 137Cs from Nari basin in Ulleung Island in the East Sea/Sea of Japan and Seongsan Ilchulbong Peak, Jeju Island showed a higher concentration at the surface layer and gradually decreased. On the other hand, the ^{137}Cs concentration in the soils collected from Bukhan Mountain National Park in Seoul showed a subsurface maximum and decreased with depth. The ^{137}Cs inventories in the soil column were calculated to be 1830 to 4360 Bq m^{-2} with a mean of

2770 Bq m^{-2} which was the same order of magnitude as the global fallout inventories in the mid-latitude region of the Northern Hemisphere.

MONITORING PHYSICAL PROPERTIES OF A SUBMARINE GROUNDWATER DISCHARGE SOURCE AT KALOGRIA BAY, SW PELOPONNISSOS, GREECE

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In this study long term time-series are presented from a monitoring project studying a submarine groundwater discharge (SGD) in Kalogria Bay, Greece. The major point source was located inside a

karstic cavity at 25 m depth. Continuous monitoring of water emanating from the major point revealed in detail, the annual cycle of the discharged water velocity, volume, and salinity variations, since they are the crucial parameters for the potential exploitation of the out-flowing water. The emerging flow and the physical characteristics of the upwelling water were recorded by means of a rotor flow meter and a CT probe. Both were deployed mounted on a metallic frame which was placed by divers at the sea bottom near / inside the karstic cavity. During dry periods the underwater discharge was not very strong and salinity values (≥ 20) were indicating brackish water outflow, while during wet periods the water outflow velocities were increased rapidly (reaching values of 0.8 - 0.9 m/s) and the recorded salinity values were decreased significantly. However, at some cases the physical properties of the water were revealed unexpected behavior leading us to consider the volatile geomorphology of the region. The out flowing water was not always concentrated as a single jet flowing from the bottom of the cave towards the surface, but it was scattered and emanated under rocks and through little cracks. In summary, the obtained monitoring data demonstrate a strongly turbulent and unstable SGD, regulated by the geomorphologic (karstic) structure of the coastal zone and modulated by factors as the local yearly precipitation cycle and the tidal regime.

A NEW ANALYTICAL METHOD TO CALIBRATE BOREHOLE SCINTILLATION DETECTORS

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The borehole scintillation detectors (with central borehole) are useful for the identification and quantification of unknown gamma-ray emitting radionuclides in geological and environmental samples due to the near 4π solid angle that can be obtained with them. In addition, the 4π gamma ray-counting is a well established method for direct activity measurements, and is especially suited for radionuclides with complex gamma-ray spectra. A straightforward theoretical approach was carried out to calculate the efficiencies (total and geometrical) of borehole scintillation detectors. The approach depends on the accurate calculation of two important factors; the path length, d, the photon traverses within the active volume of a gamma detector, and the geometrical solid angle subtended by the source to the detector at the point of entrance. These two factors are theoretically derived through straightforward analytical formulae. Furthermore, the attenuation of photons by the source container and the detector housing materials is also treated by calculating the photon path length through these materials. The comparisons with the experimental and Monte Carlo method works reported in the literature indicate that the present approach is useful in the efficiency calibration of such complicated gamma - ray spectrometer.

MEASUREMENTS OF INDOOR RADON/THORON LEVELS AND RADON IN DRINKING WATER BY USING RAD7

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Radon, thoron and their progenies are the most important contributions to human exposure from natural sources. Radon exists in soil gas, building materials, Indoor atmosphere etc. Among all the natural sources of radiation dose to human beings, inhalation of radon contributes a lot therefore it is very important to measure indoor radon/thoron levels and radon concentration levels in drinking water. The present study represents the set of measurements for indoor radon/thoron concentration levels and radon concentrations in drinking water using electronic radon meter (RAD7). The measurements have been taken for indoor air and drinking water in the dwellings of Nawanshahar district of Punjab, India. The radon concentration in drinking water has been found to vary from 1.26 to 11.00 BqL ^{1} with an average value of 4.71 BqL ^{1}. The measured indoor radon

and thoron concentration values vary from 35.15 to 264.92 Bqm ^{3} and 65.49 to 75.11 Bqm ^{3} with average values of 89.21 Bqm ^{3} and 53.87 Bqm ^{3} respectively.

ESTIMATION OF GAMMA AND BETA ORGAN DOSES DUE TO RN-222 PROGENY IN ADULT ORNL PHANTOMS

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The most important source of natural radioactivity is ^{222}Rn. For this reason, radon dosimetry has attracted quite a lot of attention which resulted in a vast number of research activities carried out in scientific communities by scientists. A great deal of work has been devoted to determine the damage caused by alpha radiation emitted from radon and its progeny. Radon-222 daughters such as and deposit in human lungs and emit gamma quanta followed by the beta particles which cause smaller damage in comparison with alpha particles. In this study dose from gamma rays emitted by radon progeny in the lungs have been calculated in all main organs using MCNP code for adult ORNL male and female.

BEHAVIOR OF RADIONUCLIDES IN WASTEWATER TREATMENT PLANTS

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Waterworks and sewage treatments facilities can produce sludge containing measurable amounts of radioactivity. The radionuclides concentrated in this process can originate from radionuclides present in the original source of water or from water treatment.

The aim of the present work is to study the temporal evolution of radioactivity in liquids and sludge generated in wastewater treatment plants because information is limited and there is an increase of usage in Spain as a result of frequent drought periods.

The activity of various radionuclides was measured in liquids and sludge from 3 municipal wastewater treatment plants in Northeast Spain. A total of 12 campaigns were carried out in different seasons in the period 2007-2009. A detailed study of radioactivity in influent, primary effluent, secondary effluent and final effluent were performed.

Two wastewater treatment plants included sedimentation and biological treatment and one also uses tertiary treatment. The residence time of the water in the wastewater treatment plants was between 1 to 4 days.

Gross alpha (co-precipitation method) and gross beta (evaporation method) activities were determined in waters and sludge by ZnS solid scintillation detectors and low-background gas-flow counters. Uranium isotopes were measured by alpha spectrometry. Gamma radionuclides (^{40}K, ^{7}Be, ^{214}Bi, ^{214}Pb; ^{210}Pb, ^{208}Tl, ^{212}Pb, ^{228}Ac) in the sludge were analyzed with a semi-conductor germanium detector.

The gross alpha and gross beta activities in the influent and effluents from the wastewater treatment plants are presented. A wide range of gross alpha activities (<0.004 to 0.129 Bq/L) and gross beta activities (0.052 to 1.53 Bq/L) in liquid samples were obtained. It was checked that gross alpha activities in influent and effluent from wastewater treatment plants were produced by uranium isotopes.

Gross alpha activities measured in sludge samples range from 58 to 203 Bq/kg and gross beta activities were between 147 to 625 Bq/kg. Mean values for gamma emitted radionuclides in samples from wastewater treatment plants were 13 Bq/kg for ^{226}Ra (^{214}Pb), 17 Bq/kg for ^{232}Th (^{228}Ac) and 165 Bq/kg for ^{40}K.

All the test procedures were validated according to the quality requirements of the ISO 17025 standard.

RADON POTENTIAL MAPPING OF PIEMONTE (NORTH-WEST ITALY): AN EXPERIMENTAL APPROACH

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Early radon studies in Piemonte, an administrative district in North-West Italy (25,200 kmq, around 4,300,000 inhabitants) were conducted since (1990-1991), when a general radon survey of the dwellings of Piemonte was performed in order to assess the average radon exposure of the whole population.

After this first step, radon researches were continued in different areas of Piemonte and involved schools as well as dwellings. These extensive radon monitoring programs led to the implementation of a large radon database of more than 3500 radon measurements distributed all over the Piemonte Region. Starting from this point it was then possible to produce a reliable radon mapping.

In order to minimize a possible bias due to the well known radon fluctuations both on daily and seasonal basis, we considered only long term measurements (annual), performed using the nuclear track etch detectors technique (LR 115 or CR-39).

The radon potential mapping of the whole Piemonte was then achieved by developing a "geolithological correlation model", based on a statistical analysis of the radon experimental data and on the underlying geological, lithological and radiometric characteristics of the soils and rocks. In this way it was possible to estimate not only the average radon levels in all of the 1209 Municipalities of Piemonte but also to assess the percentage of the population exposed to a radon concentration above a given value. This being an important achievement in order to evaluate the possible effects on health for the population.

The results showed an average value for the dwellings of Piemonte of 70 Bq/m^3, with considerable differences within the Region, being the radon levels generally lower in the Po Plain than in the mountain areas, where the average radon value in certain Municipalities exceeds 200 Bq/m^3.

A THEORETICAL MODEL FOR THE RESUSPENTION FACTOR

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The atmospheric resuspention of radionuclides is a well known phenomenon that consists in the re-injection into the atmosphere of previously deposited radioactivity. The process is driven by the action of wind on surfaces and can act as an additional source of radiation exposure by inhalation, after the deposition has finished. A resuspention factor is thus defined as follows:

$$K(t) = \frac{C_a(t)}{I_0} \quad (m^{-1})$$

generally considered as a time depending function and where Ca is the volumetric air concentration (Bq/m^3) while I_0 (Bq/m^2) is the radioactivity deposition at time t=0.

The resuspention factor concept is very useful in radioprotection in order to estimate the inhalation of radionuclides resuspended from contaminated surfaces when direct atmospheric measurements are lacking or difficult to perform.. However, the choice of the proper values of K is usually not a simple task, being quite site specific and related to the meteorological, geomorphologic and environmental characteristics of the area to be studied. Moreover, several investigations showed clearly that the values of K are a decreasing function of time. For that reasons, K values span through several orders of magnitude: typical values in the range 10^{-5} – 10^{-10} m^{-1} are reported in literature for different environmental conditions and time intervals since the deposition event. The current available models of the resuspention factor are based on empirical formulas whose parameters are highly site dependent and cannot be easily related to some physical quantity.

In this paper a simple physical model for the resuspention factor is proposed and tested with the available environmental radioactivity data (^{137}Cs), collected since 1986 (Chernobyl fallout). The new model allows not only a satisfactory description of the experimental data, as the current empirical models also do, but it is able to connect the K values to quantities with a physical meaning and that are related to processes underlying resuspention as well (such as, for example, a diffusion-dispersion coefficient).

BEHAVIOUR OF RADIONUCLIDES IN THE BACKGROUND RADIATION ENVIRONMENT

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High background radiation areas are of special interest because they present anomalous conditions in their geological and geochemical features and consequently on radiation levels. High radiation levels are attributed to the enrichment of radioactive minerals in certain geological provinces due to endogenous or sedimentary processes. Major anomalies in the concentration of radioactive minerals in soil and sand are found in two countries, Brazil and India. One of the prime sources for the high radiation background is radioactive mineral monazite, a thorium bearing phosphate mineral. In the recent years thorium has assumed significance as it is an important raw material in the nuclear fuel cycle for power generation. Though studies have been carried out on radiation level and radionuclide distribution in the high background areas, detailed studies were not reported on the enrichment of radionuclides in different size fractions of sand in the high background areas. In view of this, systematic studies were carried out to understand the selective enrichment of radionuclides in different size fractions of sand in high background area. The enrichment pattern of important minerals such as monazite, rutile, and zircon in different size fractions of sand in the high background areas were studied. The monazite content in different fractions was correlated with the thorium activity. The results of these systematic investigations area presented and discussed in the paper.

HIGHER PLANTS AS BIOMONITORS OF RADIONUCLIDES IN URBAN AIR

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The results of a multiyear study (2002—2009) on the content of radionuclides in higher plants and in air, in the city of Belgrade, Republic of Serbia, are presented. Plants are an important link in transport and distribution of radionuclides, heavy metals and other pollutants, from their source to man and environment, and are often used as biomonitors of atmospheric pollution. Since distinguishing root uptake and foliar deposition is a challenging task, higher plants are not as efficient biomonitors as mosses and lichen. However, in urban areas, where mosses and lichen are rarely found, higher plants present a satisfactory replacement.

Activities of four radionuclides, ^{7}Be, ^{40}K, ^{210}Pb and ^{137}Cs were determined in leaves of two tree genera, *Aesculus hippocastanum* L. (horse chestnut) and *Tilia spp.* (linden: *Tilia tomentosa* L. and *Tilia cordata* Mill.), both common in Belgrade city parks. The leaves were collected in 16 episodes,

and from three city parks within different Belgrade areas. The aerosol samples were collected on a monthly basis in one of the measuring locations.

Over the examined period, the differences in the activities of the measured radionuclides between the leaves of linden and chestnut are not significant. Moreover, the temporal evolution of the activities follows the same general pattern across all of the locations. Seasonal variations of the activities indicate that the predominant route of ^{40}K uptake is through the root system, while foliar deposition seems to have a more pronounced influence on the accumulation of the other radionuclides. In addition, the mean seasonal activities of ^{7}Be and ^{210}Pb in leaves agree well with the seasonal activities in air. To further examine the contribution of foliar deposition, correlation coefficients for the radionuclides' activities in leaves and aerosols are calculated.

RADON DETECTION IN MINERAL WATERS BY LIQUID SCINTILLATION TECHNIQUE AND GEOLOGICAL INVESTIGATION IN THE NORTH OF IRAN

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The generally accepted method for radon and radium activity analysis of drinking water in Iran is based on Radon Emanation method. In this study, liquid scintillation counting (LSC) technique which requires smaller sample quantities, less sample preparation time and less operator intervention has been used. In this method, an Ultra-low background Wallac-Quantulus 1220 LSC, the Mineral Oil cocktail and 20 ml Polyethylene vials were applied. Moreover, LSC technique is compared with Radon Emanation method. A total of 27 mineral spring water samples from three different areas located in the north of Iran were collected and analysed for determination of ^{222}Rn and ^{226}Ra content. The results show that the concentration of 222Rn and 226Ra in mineral waters of the studied area are from less than 0.5 Bq L^{-1} to 54 Bq L^{-1} and less than 14 mBq L^{-1} to 297 mBq L^{-1}, respectively. Besides, a good agreement between LSC and Radon Emanation results is observed. Considering high radon-content of some samples in the studied area, the geological studies have been performed.

BE-7 ATMOSPHERIC CONCENTRATIONS AT MID LATITUDES (40°N) DURING A YEAR OF SOLAR MINIMUM

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The variations of ^{7}Be concentrations in surface air of Thessaloniki, Greece (40° N) over the year 2009 a year of a deep solar minimum and as a consequence a year of maximum concentrations of ^{7}Be in surface air are presented. For first time in our measurements in Thessaloniki, Greece, we recorded a value as high as 14.6 mBq m^{-3}.The mean annual activity concentration of ^{7}Be for the year 2009 was 6.01 mBq m^{-3}. The variability of ^{7}Be surface concentrations related to the solar cycle appeared to be deviated about 20% from maximum to mean values. During a year of maximum concentrations of ^{7}Be in surface air, the differences in ^{7}Be fluctuations due to meteorological and seasonal variations are becoming easily to be revealed. The effect of temperature and relative humidity on atmospheric concentrations of ^{7}Be was studied. A positive correlation ($R=0.97$, $p<0.0001$) was revealed between the activity of ^{7}Be and the temperature T(°C). The higher activity concentrations of ^{7}Be especially during the summer period have their explanation to the solar heating of the Earth surface, which leads to the heating of the air in contact with the surface and a convective transport to be occurred carrying surface air upward and bringing downward air from higher levels enriched in ^{7}Be. The anticorrelation ($R=-0.65$, $p<0.02341$) with RH% is due to intense condensation during high relative humidity conditions, which results in increased aerosol particle sizes and as a consequence in higher scavenging rate of aerosols and lower concentration of ^{7}Be in the atmosphere. No day-night variations were revealed, while the intensity and the direction of wind velocity seem to have no influence on ^{7}Be atmospheric concentrations variability. The influence of precipitation on the ^{7}Be atmospheric concentrations variability was approximately 10%, with greater the influence of rainfall events of low precipitation rate e.g. drizzling. However, the removal of ^{7}Be from the atmosphere by rainfall events seems to be invalidated immediately after the events and the ^{7}Be concentration in air to be reestablished rapidly.

OPTIMIZATION OF PLASTIC SCINTILLATOR THICKNESSES FOR ONLINE BETA DETECTION IN MIXED FIELDS

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A Monte Carlo simulation model has been built to optimize the thickness of plastic scintillator, used in whole body monitor, for efficient beta detection in a mixed field beta gamma field. The simulation has been performed using MCNP/X code and different thicknesses of plastic scintillator staring from 0.15 to 0.6 mm. The relationship between the thickness of the scintillator and the

efficiency of the detector has been analyzed. For 0.15 mm thickness an experimental investigation has been conducted with different gamma sources at different positions on the scintillator and the counting efficiency of the unit has been measured. Evaluated data along with experimental ones will be discussed.

RADIOACTIVITY IN THE INDUSTRIAL EFFLUENT DISPOSED SOIL

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Studies on radiation and radioactivity distribution in the soils of effluent disposed from sugar industry at south Tamil Nadu, India had been conducted. The aim of this study was to explore the radiation level and to provide the baseline data for the further assessment of the impact of the industrial effluents. The external gamma dose rates in air have been measured throughout the study area using an Environmental Radiation Dosimeter. The activities of naturally occurring radionuclides in the soil samples were also measured using NAI(Tl) gamma ray spectrometry. The soil samples were also subjected for various physicochemical analyses. This study revealed that mean value of ^{232}Th, ^{238}U and ^{40}K activities were 40.06 Bq kg^{-1}, 22 Bq kg^{-1} and 246.32 Bq kg^{-1} respectively and when compared to the world average value (30 Bq kg^{-1}) the concentration of ^{232}Th activity is higher almost by a factor of 1.33 while the concentration of ^{232}U and ^{40}K are found lower than world average value. It was also observed that the mean activity of ^{232}Th and ^{238}U were found higher values compared to the Indian average value by a factor of 1.55 and 2 times respectively. A moderately good correlation between the heavy metals presented in the soil samples and the ^{232}Th activity was observed.

STABLE ISOTOPES AS TRACERS OF SUBMARINE GROUNDWATER DISCHARGE

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Stable isotopes of water (^{2}H and ^{18}O) have been used for tracing submarine groundwater discharge in coastal zones. They have been analysed in precipitation, river water, inland groundwater, submarine discharge and seawater with the aim to better understand groundwater-seawater interactions in the region and to quantify groundwater admixture in submarine

discharge. Examples of isotope investigations of submarine groundwater discharge in south-eastern Sicily (Italy), eastern Brazil and western Mauritius are presented and discussed.

MONITORING OF RADIONUCLIDES IN THE AIR OF MONACO DURING 1997-2009

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IAEA-MEL has been carried out monitoring of radionuclides in the air of Monaco for many years. Several natural (cosmogenic, radiogenic and primordial) and anthropogenic radionuclides have been found in the atmosphere. The measurements have been used to study temporal variations of radionuclides, to detect any irregularities in their concentrations resulting from natural events or human accidents, as well as to estimate their deposition rates to Mediterranean Sea. Temporal variation of ^{137}Cs in air at Monaco from 1997 to 2009 is presented below. The peak observed in June 1998 was due to the Algeciras (Spain) accident.

ANNUAL EFFECTIVE DOSE DUE TO COMBINED CONCENTRATION OF RA-226 AND RA-228 IN GROUNDWATER SYSTEM: A CASE STUDY OF UNIVERSITY OF ILORIN MAIN CAMPUS, NIGERIA

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An estimation of the annual effective dose received by the population as a result of the ingestion of ^{226}Ra and ^{228}Ra in groundwater within the Main Campus of the University of Ilorin, Nigeria has been made. Groundwater samples from existing boreholes sited inside the campus were analyzed by γ-ray spectroscopy to determine the suitability of the water for human consumption. The activity concentration values from the analysis range from 0.03±0.02 to 4.79±1.26 Bq L^{-1} for ^{226}Ra and from 0.01±0.00 to 4.79±1.82 Bq L^{-1} for ^{228}Ra. The computed annual effective dose received by the population as a result of the ingestion of ^{226}Ra and ^{228}Ra is thus estimated to range from 0 to 0.49 mSv y^{-1} and 0.003 to 1.21 mSv y^{-1} respectively. The total annual effective dose received as a result of the combined ingestion of ^{226}Ra and ^{228}Ra is consequently found to range from 0.003 to 1.45 mSv y^{-1} with an average of 0.59 mSv y^{-1}. It is therefore, observed that although the average combined contribution of ^{226}Ra and ^{228}Ra activities to the committed effective dose from a year's consumption of drinking water in the study area is less than the ICRP's recommended limit of 1 mSv y^{-1}, the groundwater from some of the boreholes are more than 1 mSv y^{-1}. For this reason, it is recommended that adequate measures should be taken to protect the youthful populace in the study area from consuming radiologically unsafe drinking water from the affected boreholes.

THE DIURNAL AND SEASONAL VARIATIONS OF RADON AND ITS PROGENY CONCENTRATIONS IN THE LOWER ATMOSPHERE OF BANGALORE, SOUTH INDIA

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The measurements of radon and its progeny concentrations in outdoor air were carried out simultaneously with a time interval of 2 hours for a period of 3 days in every month for one year near the department of Physics, Jnanabharathi, Bangalore. The Low Level Radon Detection System (LLRDS) and air flow meter with glass micro fibre filter paper were used to measure the concentrations of radon and its progeny respectively. The diurnal and seasonal variations of radon and its progeny, meteorological parameters and the variations in the equilibrium factors were studied. The influence of meteorological parameters such as temperature and humidity in the variation of radon and its progeny concentrations were also studied. The linear regression technique was used to analyze the variations of radon and its progeny concentrations in the lower

atmosphere. Average daily pattern of radon and its progeny concentrations in the lower atmosphere featured a minimum in the late afternoon and a maximum in the early morning hours. While seasonally the concentrations attain maximum average in winter and a minimum average in rainy. The winter/rainy ratio of radon and its progeny concentrations are found to be 1.75 and 2.31 respectively. The annual geometric mean values of radon and its progeny in outdoors are found to be 8.2 ± 2.5 Bq m^{-3} and 0.46 ± 0.16 mWL, respectively.

ABERRANT CELL DIVISIONS IN ROOT MERISTEMS OF MAIZE FOLLOWING EXPOSURE TO X-RAYS LOW DOSES COMPARED TO SIMILAR EFFECTS OF 50 HZ ELECTROMAGNETIC EXPOSURE

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The maize response to radiation exposure was investigated by both cytogenetic methods considering the importance of genotoxic effect for environment and agricultural purposes. Uniform genophond seeds, freshly germinated were exposed to relatively low radiation dose array using radiotherapy X-ray applicator from hospital irradiation device. Root meristeme aliquots were taken for cytogenetic investigation based on microscopic observations and cell counting. Microscope slides were prepared by specific procedure (squash technique and Fuelgen method based on modified Carr reactive coloration). Aberrant cell divisions were counted and classified for every mitosis phase. Mitotic index as well as chromosomal aberration were calculated for more than 30,000 cells taken into account. The same protocol of sample preparation and quantitative investigation was applied to root meristeme samples provided by maize seeds exposed to 50 Hz electromagnetic field with about 10 mT magnetic induction (generated within laboratory electromagnetic coils). Chromosomal aberrations such as interchromatidian bridges, retard and expulsed chromosomes and chromosome fragments were evidenced from the viewpoint of qualitative analysis – together with rare micronuclei. Comparison was carried out between the curves of mitotic index versus irradiation times underlying the potential risk of environmental exposure to atmospheric radiation background but also the plant sensitivity to electromagnetic low frequency fields. Dose-response functions were proposed for the chromosomal aberration percentage versus radiation exposure intensity. One may conclude that the radiation sensitivity of maize during early ontogenetic stages is important also for biotechnological applications considering potential control of plant growth by means of physical factors of electromagnetic nature.

PATHOGEN GERMS RESPONSE TO LOW DOSE RADIATION – MEDICAL APPROACH

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The side effect of radiation therapy mediated by microbial loading of irradiated organs was considered as phenomenological basis of the experiment carried out on Staphylococcus aureus (ATCC germ) exposed to X-ray irradiation. The inoculums was prepared in liquid culture medium with standard composition, the 3 mL identical samples (in sterile glass tubes) being irradiated in hospital conditions. Five experimental variants were developed corresponding to irradiation time durations between 25 and 100 minutes. Spectro-colorimetric assay was accomplished at 560 nm and 420 nm – the resulted average values (for three repetitions) being analyzed from the viewpoint of cell density in the irradiated variants compared to control ones. The resistance to antibiotics of the irradiated bacteria was tested on agarized cultures against five antibiotic molecules: ampicillin, cloramphenicol, tetracycline, tobramicin and ofloxacin, by assessing the diameter of inhibition growth areas in each case. The increase of the inhibition area diameter with up to 15% (in the case of tetracycline) was noticed for the lowest irradiation time for all five antibiotics – suggesting the lowering of the bacteria resistance to the pharmaceutical agents following X-ray treatment. This was concordant with the results of the spectro-colorimetric assay of the cell density within the directly irradiated bacteria cultures. The main issue of this study is concerning the optimization of the radiotherapy protocol in patients with potential microbial loading.

CHARACTERIZATION OF A $LaBr_3$ GAMMA-RAY SPECTROMETER FOR AMBIENT DOSE EQUIVALENT RATE H*(10)

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Experimental gamma exposures together with Monte Carlo simulations using the PENELOPE code have been performed for the characterization of a gamma spectrometer probe, based on a $LaBr_3$ scintillator, developed by the German Federal Office for Radiation Protection (BfS). The

experimental exposures were carried out in the accredited calibration laboratory of the Institute of Energy Technologies of the Technical University of Catalonia (INTE) following the ISO 17025 standard. The $LaBr_3$ is a 1" diameter cylindrical BrilLanCe380 crystal detector from the Saint-Gobain Company mounted together with a XP2060 Photonis photomultiplier tube (PMT) and an AS2712 preamplifier. The signal is acquired by a digital multichannel analyzer (MCA) from the XIA Company. Laboratory exposures were carried out using ^{241}Am, ^{137}Cs and ^{60}Co sources in order to characterize the sensitivity of the measured ambient dose equivalent rate (H*(10)) to energy, angular gamma-ray direction and temperature. Monte Carlo simulations for surface radioactivity contamination and air radioactive cloud are presently being conducted in order to analyse the probe response to hypothetical radioactive releases. Both experimental exposures and the Monte Carlo simulation results will be presented in this paper.

EXPERIMENTAL AND MODELLING STUDY OF THE UPTAKE KINETICS OF SR-90, BA-133, CD, CO, CR, AND PB IN NATURAL AQUEOUS SUSPENSIONS IN THE GIBRALTAR STRAIT

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Studies on radionuclide and heavy metal behaviour in natural waters are of interest because of their high particle-affinity, their complex chemical behaviour in natural systems, and their effect on human and environment health in relation to accidental spillage and planned release.

Interest in the uptake kinetics of radionuclides and heavy metals in natural aqueous suspensions has recently increased in order to understand and reliably model the dispersion of wastes in aquatic environments. The approaches based on the uptake kinetics are more appropriate than those based on the distribution coefficients, k_d.

The amount, nature and dynamics of the suspended loads highly influence the behaviour of particle-reactive radionuclides and heavy metals. The kinetics of this process has a very fast component. Changes in pH, temperature and in the electrical conductivity are influencing the uptake kinetics and the final partitioning of the radioactivity.

We developed a numerical model able to reproduce the observed kinetic uptake in all the studied cases. Then this model was adapted and incorporated into a kinetic reactive transport model for aquatic systems. The kinetic coefficients (and the factors which affect their variability) can be experimentally determined for each natural system of interest. This model represents then a powerful tool to study basic processes in natural systems when it is coupled to the dynamic of suspended load concentrations.

PRACTICAL POSSIBILITY TO PREDICT AND CONTROL RADIONUCLIDE CONTAMINATION OF WATER BY THE EXAMPLE OF THE REGION OF KRIVOY ROG

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Heavily anthropogenic loading on ecosystem of the Dnepr River basin have resulted in degradation of all ecosystems and in particular to violation access to safe and adequate water and sanitation services in the whole regions of Ukraine. One of most critical in relation to quality of living conditions and quality of water supply is the region of Krivoy Rog supersaturated by mountain enterprises. Uranium deposit located near-by Zoltje Vody City in the region of Krivoy Rog is one of the largest on territory of Ukraine. One of main mining objects of the city is a mine «Nova», which works mine of ferrous and uranium ores. Mine water which is pumped out on a surface saturated by uranium, sulfides, chlorides and is used for the technological necessities of mining complex and farther brushes off in tailing dump from where surpluses of water brush off in a Zoltaja River. Concentration of radionuclide contamination in 10 - 15 times exceed normative during the events. This in the turn, results in contamination of waters of Ingulets River (tributary of the Dnieper River) and Karachunovskoe reservoir - basic source of water-supply of whole region.

In work are examined efforts directed to decreasing of possible consequences of conflict events of volley inflow of the muddy by radionuclide mine waters in Zoltaja River, prognostication of possible consequences of such catastrophic situations and study of possibilities of direct influence on flow of incident by application of water protection measures.

Results of calibration of the model on a dataset of field measurements through critical 1994, a comparison with the box model for complete mixing and validation on data (^{90}Sr) through 1991, 1999 critical situations (the Kiev reservoir Dnieper River) are given. The post-Chernobyl measurements were used.

The practical efforts to mitigate consequences of the protracted catastrophic manmade influence on a water environment and possibilities of gradual maintenance of the water system in the whole region of Krivoy Rog are analyzing in the work. Possibility of water protection is explored at the catastrophic discharge of mine water to Zoltaja River by dilution by waters from the storage pool of Ingulets River and washings by waters of Dnieper River. Such measures in many cases enable to access to safe and adequate water and sanitation services during the catastrophic events. For providing of the operative use a program complex the interface of user which provides the task of initial data and receipt of results of calculations in the graphically formalized kind was developed. Results of modeling of escape of mine water of muddy by ^{238}U to Zoltaja River and water protection actions are given.

The principle possibility of re-building of water system is demonstrated. It is possible by the long time gradual complete discharge of mine waters from tailing dumps through the water system.

EXPERIMENTAL STUDY OF FEATURES OF ARTIFICIAL RADIONUCLIDES TRANSITION TO ORGANS AND TISSUE OF SHEEP UNDER SNTS CONDITIONS

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The paper presents the results of field studies on the characteristics of the artificial radionuclides transition into the organs and tissues of sheep under different conditions and timing of their flux. Studies have been conducted at "Degelen" experimental site (ES) of Semipalatinsk test site (STS). We took the Kazakh fat-rumped coarse wool sheep breeds as the subject of research.

There was performed quantitative estimation of uptake of radionuclides ^{3}H, ^{137}Cs, ^{90}Sr, $^{239+240}Pu$ and ^{241}Am with the components of the environment: air, water and vegetation. It was determined that the main source of uptake of radionuclides ^{137}Cs, ^{90}Sr in animals is plant food, for ^{3}H - tunnel water.

In general, the presented findings in this paper confirm the existing data on the nature of metabolism of radionuclides in animals. However, the obtained transition coefficient (C_t) of ^{90}Sr and ^{137}Cs into muscle tissue of sheep, in the equilibrium state proved to be one order of magnitude less than the average values of C_t presented in the IAEA database. Maybe it depends on different forms of ingestion intake. So the radionuclides C_t according to our records, at different intake with water or food, may vary up to one order. Perhaps C_t values are affected by the natural and climatic features (differences of micro-, macro-element composition of environment components, especially the concentrations of stable Sr and Cs and their chemical analogues in feeds) as well as the species of radionuclides in environmental media.

The results obtained allow regulating the daily rate of radionuclides, excluding excess of hygienic requirements for food products that are essential in assessing the possibility of the STS lands in the national economy.

Determined dependence of distribution of radionuclides ^{90}Sr, ^{137}Cs and ^{3}H among organs and tissues allows by one organ to determine the content of radionuclides in the whole body, or even, giving a preliminary assessment of radionuclide concentrations in organs and tissues of wool without slaughtering the animal. It should be noted that we have not found similar work carried out previously.

DETERMINATION OF THE RADIOACTIVE ELEMENTS IN FISH OF THE ARABIAN GULF

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Fish is one of the main sources of food in the Kingdom of Bahrain and most countries in the Arabian Gulf region. The Arabian Gulf is congested with marine traffic such as oil tankers, commercial ships and naval vessels; some of which are nuclear powered. In addition depleted Uranium was heavily used during the Gulf wars from 1990 to 2003. Therefore, the Arabian Gulf waters could be contaminated by some radioactive materials which in turn lead to higher levels of radioactive materials present in fish in this region. This work is carried out to measure the level of radioactive materials present in fish with special emphasis on ^{137}Cs, ^{134}Cs and ^{40}K, using a high purity Germanium detector. Four kinds of the most commonly consumed fish in Bahrain were tested. The results of the measurements will be presented.

RADIOECOLOGICAL IMPACTS OF NORM FRACTIONATION IN PHOSPHATE ROCK BENEFICIATION PROCESSES

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Beneficiation processes (crushing, screening, washing, magnetic separation and wet screening) of phosphate rock aims to increase the phosphorus content of the run-of-mine (ROM) ore. It starts with the ROM ore and ends with the wet rock, and different rejects (by-products). These rejects are massive, 1.8 Mt annually, about 45% of ROM ore. They have a potential environmental hazards due to their content of Naturally Occurring Radioactive Materials – NORM, especially uranium-238 series. They have also potential industrial and agricultural useful applications due to their physicochemical properties such as relative high content of phosphorus, clay and iron. Representative samples of ROM ore, wet rock, and beneficiation processes by-products (wet screening, magnetic separation, slim, and clay and dolomite rocks) were collected. Natural radionuclides (^{238}U, ^{235}U, ^{232}Th, ^{40K}, ^{210}Pb, ^{210}Po) were measured using gamma-ray spectrometer, alpha particle spectrometer and ICP-MS analytical techniques. Radiologically, internal hazards index, external hazard index, representative level index, gamma absorbed dose rate and occupational dose equivalent due to inhalation were calculated. Potential hazards due to beneficiation processes and their by-products were discussed. Some of the by-products could have potential useful applications such as clay rock and slim for agricultural soil reclamation.

DEVELOPMENT OF A MULTI-CRITERIA ANALYSIS SYSTEM TO SUPPORT DECISION PROCESSES IN RADIOLOGICAL EMERGENCIES IN A TROPICAL CLIMATE COUNTRY

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One of the permanent concerns in the international scenario is the study of the consequences of nuclear and radiological accidents and other events that lead to the contamination of the environment and the exposure of members of the public as a consequence of this contamination. Decision-making in such situations need to be based in solid technical criteria but must also take into account the actual prevailing circumstance in order to reach optimized measures to protect people and the environment. The Multi-criteria Analysis Method is already being used for similar applications in some European countries but it is necessary that the criteria are established taking in account economic, social and climatic aspects that can affect the selection of protective measures applicable to specific regions, and the selection of the different weights to be associated to the different criteria that are to be applied to different social-politic environments. The present work describes the development of a Multi-criteria tool to support the decision making process for the implementation of protective measures to protect the public in situations of radiological accidents, with the degree of flexibility to be easily adapted to the different social, political and climatic regions of Brazil, through the comparison of different options considering a diversity of aspects, such as the efficiency of the measure in the reducing public exposure, the radiation doses that would be received by the workers, the characteristics of the generated wastes, the difficulty of implementation of the measures, as well as the operational costs related to the implementation of the measures. For urban areas, it was relatively simple to derive radiological criteria to feed a decision making process, as the percent reduction on doses for several countermeasures have not shown large variation among the different scenarios simulated. For rural areas, the decision process needs to consider the specific situation of the affected area, considering source term characteristics, soil type, seasonal aspects, local management practices and ingestion habits of affected populations, particularly the self-sustaining ingestion of relevant food items. The paper describes the steps already developed and the current status of the system under development, discusses the difficulties found and stresses the needs for future developments.

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