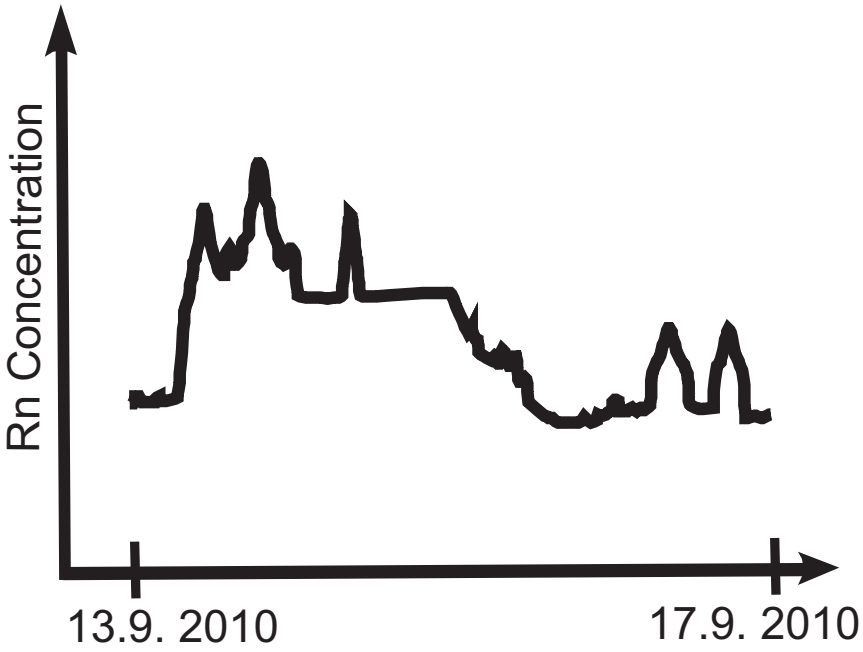
6th Conference on Protection Against Radon at Home and at Work



PRAHA 2010

Book of Abstracts

6th Conference on Protection Against Radon at Home and at Work

BOOK OF ABSTRACTS

September 13 -17, 2010

Prague, Czech Republic

Radon 2010

Book of Abstracts

Czech Technical University in Prague
Faculty of Nuclear Sciences and Physical Engineering
Břehová 7, 115 19 Praha 1, Czech Republic
CTU publishing, Thákurova 1, 160 41 Praha 6
Prague, 2010

Editors: Tomas Urban, Katerina Rovenska, Jiri Martincik
Number of pages: 161
Number of copies: 150

ISBN 978-80-01-04603-6

6^{th} Conference on Protection Against Radon at Home and at Work

13 -17 September 2010,
Prague, Czech Republic

Organized Jointly by

Faculty of Nuclear Sciences and Physical Engineering,
Czech Technical University in Prague

and

National Radiation Protection Institute, Prague

Conference secretariat

Faculty of Nuclear Sciences and Physical Engineering
Czech Technical University in Prague
Břehová 7, 115 19 Prague 1, Czech Republic
Phone: (+420) 224 358 256, (+420) 222 314 132
Fax: (+420) 224 811 074
Webpage: `www.radon2010.cz`
E-mail: `radon@radon2010.cz`

EXHIBITORS

The organizers sincerely thank to the companies who supported the conference financially.

Gammadata	www.gammadataradon.com	
Saphymo GmbH	www.genitron.de	
Tracerlab	www.tracerlab.com	

FOREWORD

Dear RADON 2010 International Conference participants!

Two important events centered on *radon problematic* take place in Prague this autumn - **6^{th} Conference on Protection Against Radon at Home and at Work** and **10^{th} International Workshop on the Geological Aspects of Radon Risk Mapping**. Both conferences have long tradition and the organizers are pleased that despite of the economic crisis, the scientists are still quite interested in radon issues. We will be presenting for discussion several new findings from the field practice, as well as resulting from scientific research.

The RADON 2010 is traditionally organized by CTU a NRPI. The invited lectures will be given by mavens like Ms. Annette Roetger, Ms. Margot Tirmarche, Mr. Francesco Bochicchio, Mr. Harry Friedman, Mr. Werner Hofmann and Mr.Martin Jiranek. The young generation will be represented by Ms. Ivana Fojtikova and Mr. Ales Fronka. The American view on radon problematic will be presented by the president of American Association of Radon Scientists and Technologist (AARST) Mr. William Angell. The tele-bridge created during the last Conference in 2007 has endured and we hope that the cooperation between European and American radon communities will be developing further. Our guest of honor will be Charles R. Carrigan whose lecture subject - radioactive gas as a tracer - is quite closely related to the main theme of the Conference: **Radon as an information carrier**. Let us collectively develop this point of view: take an advantage of radon's properties and capabilities, and do not see the radon only as "silent murderer creeping in the bedroom".

Sixty nine talks and forty two posters form challenging, and we hope valuable, conference program. The best contributions will be afterward published in the RPD and the Conference outcome will be presented and disseminated among other parties interested in radon problematic.

Dear Conference participants, you are welcome to the official conference program, and beside that to the relaxed venues of information exchange in the cool Czech pubs, so conducive for the informal talk about radon, about possible collaboration, about anything you want.

We hope the Conference will be rewarding for you.

On behalf of organizing committee,

Katerina Rovenska and Lenka Thinova

CONTENTS

Methods of measurement - devices, metrological aspects

oral presentaions

Recent Developments in Radon Metrology: New Aspects in the Calibration of Radon, Thoron and Progeny Devices

Annette Röttger, Anja Honig

Radon Measuring Technique, Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, Braunschweig, D-38116, PTB, Germany

annette.roettger@ptb.de

Radon and its progenies cause the highest global radiation exposure due to natural radiation sources worldwide. Since the activity concentration of radon in the environment can vary over five orders of magnitude, it is a challenge to both metrology and radiation protection.

Due to the importance of reliable measurements of the radon activity concentration, the past developments in metrology were applied to the field of radon, thus meeting two basic needs: (1) the harmonization of metrology within the scope of the Mutual Recognition Arrangement (MRA), an arrangement drawn up by the International Committee of Weights and Measures for the mutual recognition of national standards and of calibration issued by national metrology institutes and (2) the increased demands of the EURATOM directive, transferred into national radiation protection regulations with regard to natural radioactivity and its quality-assured measurements.

An overview of typical technical procedures in the Radon Measuring Technique Group of the PTB, covering all these aspects of reference atmospheres (primary standards) for radon, thoron and their respective progenies is presented and their impact on the usage of reference devices (secondary standards) is discussed.

Comparative Analysis of Radon, Thoron and Thoron Progeny Concentration Measurements

Miroslaw Janik, Shinji Tokonami, Tetsuo Ishikawa, Atsuyuki Sorimachi, Maashiro Hosoda, Chutima Kranrod

National Institute of Radiological Sciences, 4-9-1 Anagawa, Inage-ku, Chiba, 263-8555, Japan

mirek@fml.nirs.go.jp

Inhalation due to radon and its short-lived decay products as well as thoron series accounts for an about half of the effective dose from natural radiation sources. In the past radon studies were more popular than those of thoron but recent studies on the Serbia, China and India dwellings show that thoron can be a significant contributor to the radiation exposure. Based on several surveys conducted all over the world, examinations of correlation between radon, thoron and thoron progeny were carried out in this study. For this purpose passive detectors developed or modified by National Institute of Radiological Sciences (NIRS) were used. Radon and thoron concentrations were measured by passive discriminative radon-thoron detector (RADUET). Thoron progeny measurements were conducted with the NIRS modified detector, originally developed by Zhuo and Iida. This monitor detects only high alpha energy particles emitted from ^{212}Po, which is one of the thoron decay products. Calibration factors of these detectors are obtained using the NIRS radon and thoron chambers. Qualities of results are systematically studied through comparison with other type of detectors during international intercomparisons. In the result of measurements weak correlations between radon and thoron as well as thoron and thoron decay products are found out. This result indicates that they are independent parameters, so it is difficult to estimate one concentration with the other one.

Statistical Model of Quality of Radon Measurements using Electret Ion Chamber Detectors

Renata Dubcakova[1], Pavel Praks[2], Ladislav Moucka[3]

[1] *Faculty of Safety Engineering, VSB - Technical University of Ostrava, Lumirova 13, Ostrava, 700 30, Czech Republic*
[2] *Faculty of Electrical Engineering and Computer Science, VSB - Technical University of Ostrava, 17. listopadu 15, Ostrava, 70833, Czech Republic*
[3] *National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic*

pavel.praks@gmail.com

This paper presents a statistical model for estimating probability that a quality of radon measurements using electret ion chamber system RM-1 will be (in)accurate. The exact radon concentration in the air was estimated by two different ways: i) by measurements of the continuous radon monitor and ii) by statistical estimation from large sets of independent electret detectors (in sum 258).

The quality of the electret measurement was modeled as a ratio between the exact radon concentration and the radon concentration obtained from the electret ion chamber. When the ratio between the exact and electret-based radon concentrations was within 20% limit, the quality of the electret measurement was classified as accurate. Otherwise, the electret measurement was classified as inaccurate. In order to estimate the uncertainty of the statistical model, the exact confidence limits for the estimated probabilities are computed. The statistical model was confirmed by an independent set of measurements. Moreover, the effect of absolute humidity for quality estimation of electret detectors are also statistically analyzed and discussed. The results of the statistical model confirm that the electret system is robust and suitable for estimation of radon concentration.

Four Passive Sampling Elements (Quatrefoil)– I. Monitoring Radon Gas and its Progeny by Surface-Contamination Monitors

Luigi Tommasino[1], Shinji Tokonami[2]

[1] *THL, Via Cassia 1727, Roma, 00123, Italy*
[2] *National Institute of Radiological Sciences, 4-9-1 Anagawa, Inage-ku, Chiba, 263-8555, Japan*

ltommasino@gmail.com

Four passive sampling elements (quatrefoil) have been recently developed, which transform a radionuclide volume-activity into a surface-activity one. These samplers, once exposed, result in thin radiation sources which can be detected by any real-time or passive detector.

In particular, by using a large collecting-area sampler with a low surface density (g/cm^2), it is possible to measure radon and its decay products by beta surface- 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 simply by a pancake G.M. counter.

Emphasis will be given to those measurements, which are difficult, if not impossible, to carry out with existing technologies. Alternatively, these new passive samplers make it possible to use radon-decay products as tracers for the detection of all airborne particles.

Four Passive Sampling Elements (Quatrefoil)– II. Film Badges for Monitoring Radon and its Progeny

Luigi Tommasino[1], Shinji Tokonami[2]

[1] *THL, Via Cassia 1727, Roma, 00123, Italy*
[2] *National Institute of Radiological Sciences, 4-9-1 Anagawa, Inage-ku, Chiba, 263-8555, Japan*

ltommasino@gmail.com

The four passive samplers (quatrefoil), already described in a parallel paper, make it possible to obtain thin radiation sources, useful for alpha- and beta-counting by any passive and real-time detector.

In the present paper, the applications of this quatrefoil for measuring radon and its progeny by tract-etch detectors will be described.

In the case of radon measurements, different solids have been identified, with radon partition coefficients from 1 to 2000. Uniquely compact radon badges can be obtained by using a thin layer of these materials against an alpha track-etch detector.

These radon badges make it possible to overcome most of the shortcomings of existing passive monitors. Moreover, these badges show promise for studying the radon solubility of polymer films.

Because of the plate-out, the bare CR-39 detector has been of little or no use for radon measurements. By contrast, the plated-out radon decay products can be successfully exploited for the dose assessment.

International Standardization Work on the Measurement of Radon in the Atmosphere and Water

Dominique Calmet[1], Roselyne Améon[2], T. Beck, A. Bombard, S. Brun, Peter de Jong, M. Forte, M. Fournier, M. Herranz, M. Hollensteiner, S. Jerome, A. Klett, P. Kwakman, M. Llaurado, J. Loyen, P. Michel, P. Nardoux, T. Richards, C. Schuler, Shinji Tokonami, M. Woods

[1] *CEA, France*
[2] *IRSN, France*

roselyne.ameon@irsn.fr

Radon is today considered to be the main source of human exposure to natural radiation. As stated by the World Health Organization, the exposure due to the inhalation of indoor Rn is much greater than that due to the ingestion of water because of the Rn degassing from water during handling. In response to these concerns about the universal presence of Rn, environmental assessment studies are regularly commissioned to assess the Rn exposure of the public. The credibility of such studies relies on the quality and reliability of Rn analysis as well as the sample representitivity of the radiological situation. The standard-setting approach, based on consensus, seemed to lend itself to a settlement of technical aspects of potential comparison. Two Working Groups of the International Standardization Organization (ISO) are presently focused on drafting standards on Rn measurement in the atmosphere and water. These standards, which endeavour to set up rigorous metrology practices for measuring Rn, will be useful for persons in charge of the initial characterization of a site with respect to natural radioactivity as well as to those performing the routine surveillance of specific sites.

Primary ^{222}Rn Measurement Equipment by the Authorized Metrological Center in the Czech Republic

Ivo Burian, Petr Otahal, Josef Vosahlik

Nuclear Department, National Institute for Nuclear, Chemical and Biological Protection, v.v.i., Kamenna 71, Milin, 26231, Czech Republic

otahal@sujchbo.cz

The new radon chamber was constructed at the Authorized Metrological Center in the Czech Republic. This new radon chamber is modern version of the Razés chamber. This chamber consists of an air-conditioned walk-in testing chamber of 10 m^3 volume, in which the environmental parameters (temperature, air humidity and aerosols content) can be changed and controlled. It is possible measure all climatic parameters as well as concentration of radon and its decay products. The radium needles in uranium shielding are the source of radon. The range of certification measurements is from 150 to 1 000 000 $Bq \cdot m^{-3}$. The environment for calibration is not only new radon chamber, but also new testing room, where the real conditions are similar to dwellings. Here the concentrations could be changed to be in ambient indoor region.

Development of a Multi-purpose Radon Calibration Chamber

Carla Poliana Souza, Clovis A. Hazin, Eliane V. Honorato

Centro Regional de Ciências Nucleares - NE, Comissõ Nacional de Energia Nuclear, Av. Prof. Luiz Freire, 1000, Recife - PE, 50740540, Brazil

chazin@cnen.gov.br

A radon chamber was built at the CRCN-NE/CNEN. Besides its detector calibration capability, the chamber can also be used for determining radon exhalation rates from several materials. The 0.84 m^3 chamber has two compartments which can be completely isolated one from the other so that two parallel experiments can be performed simultaneously. Radon is generated by a dry ^{226}Ra flow-through source. Air is supplied by a small air pump which is capable of providing a variable output, according to the source manufacturer recommendations. At steady state operation, air passing through the source at a flow rate of 1 L min^{-1} will exit with a radon concentration of 12.6 Bq L^{-1}. Radon concentrations ranging from 1.26 to 25.20 Bq L^{-1} can be attained for air flow rates varying between 10 and 0.5 L min^{-1}, respectively. This radon concentration can be monitored by sampling air (grab or continuous sampling) through one of the several sampling ports existing in the chamber walls.

Logistic of Surveys of Retrospective ^{222}Rn Concentrations by Home Stored CDs/DVDs

Ivelina Dimitrova, Dobromir Pressyanov, Strahil Georgiev, Plamen Yankov

Faculty of Physics, University of Sofia "St. Kliment Ohridski", 5 James Bourchier Blvd., Sofia, 1164, Bulgaria

pressyan@phys.uni-sofia.bg

Recently, a method for rather precise retrospective ^{222}Rn measurements, based on home stored CDs/DVDs, has demonstrated a promising potential for wide application. In Bulgaria, pilot surveys have been initiated, based on voluntarily provided CDs/DVDs. The results showed that large scale surveys could be efficiently organized. However, several problems were identified and are discussed in the report. The first is the relatively small number of participants (about 50%) that actually provided disks. Other addressed topics include the compatibility between results of different disks from one place, the accuracy of dating CDs/DVDs and the possibility for individual a posteriori calibration of each disk. The possibility to follow year-to-year variations by disks of different age is also discussed.

A Calibration Setting with Uncertainty Measurements for Passive/Active Radon Monitors Using Flow-through Source Type

Seyed Mahdi Hosseini Pooya[1,2], Mehran Taheri[1], Mansour Jafarizadeh[1,2], Ali Akbar Kazemi Movahhed[1,2], Darush Marzbani[1]

[1] *National Radiation Protection Department (NRPD), Iranian Nuclear regulatory Authority (INRA), End of karegar shomali St., Tehran, 14374, Iran*
[2] *Radiation Application Research School, Nuclear Science & Technology Research Institute (NSTRI), Tehran, Iran*

mhosseini@aeoi.org.ir

Based upon the steady flow method, a setting has been introduced for calibration of almost all types of active monitors and passive dosimeters of radon using flow-through sources. In this method, a traceable radon reference source (Pylon Electronics Inc.) is connected to a portable rectangular cubic transparent chamber (volume of 50 liters) which is completely sealed and has 6 valves on its sides. The initializing calibration times are less than 150 minutes by this chamber. The radon concentration in the chamber is in consistent with the source activity. The uncertainty has been calculated within the range of 7.5% to 8% with 95% confidence level depending upon what kind of radon monitor are used. As well by using grab-sampling method, the difference of radon concentration of different points in the chamber was measured less than 3%. So the flow-through sources can be developed for a fast calibration of almost all types of the radon monitors with an acceptable uncertainty using this calibration setting.

The Radon Map of Vojvodina – Experiences and Conclusions

Sofija Forkapic, Istvan Bikit, Dusan Mrda, Natasa Todorovic, Jovana Nikolov

Department of Physics, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovica 4, Novi Sad, 21000, Serbia

sofija@df.uns.ac.rs

The comparison of three annual radon maps of South-Pannonian Province Vojvodina (Serbia) is presented. The presence of numerous underground hot spring and sources of natural gas, as well as some crude oil reservoirs in Vojvodina point to the possibility of elevated radon levels. Indoor radon concentrations were measured by alpha track detectors CR-39 on about 1000 locations in 45 municipalities each year (2003-2005) during the winter. The main aim of the present study was to exploit the critical group of population for radon exposure. From geometric mean annual radon activity concentrations the annual doses were estimated and for each year they are above the recommended action limit of ICRP. From radon mapping experiences future possibilities of improving data collection and analysis are discussed.

Combination of Geological Data and Radon Survey Results for Radon Mapping

Michael Zhukovsky, Ilya Yarmoshenko

Institute of Industrial Ecology UB RAS, Yekaterinburg, Russia, Sophy Kovalevskoy st. 20, Yekaterinburg, 620219, Russia

michael@ecko.uran.ru

The typical way of radon mapping usually used in most countries is the presenting of average radon concentrations in dwellings for districts or regions. Sometimes the maps of radon concentrations in the soil or maps of percentage above the reference level also demonstrated. Such approach not always can be used for identification of the regions with high probability of radon exposure above the reference levels were the population density is low. The combination of archive geological data and the results of representative radon survey allow estimating the typical parameters of radon concentration distribution for selected categories of buildings (multistorey or rural type houses) situated in geological zones with the different radon potential. In this case it is possible to give grounds for the necessary level of radon protection measures in the new buildings constructed in this region. The use of such approach in Ural region of Russia is demonstrated.

Status of the European Indoor Radon Map

Tore Tollefsen[1], Marc De Cort[1], Valeria Gruber[1], Peter Bossew[2]

[1] *European Commission - DG JRC, Ispra, Italy*
[2] *Bundesamt fuer Strahlenschutz, Berlin, Germany*

tore.tollefsen@jrc.ec.europa.eu

To explore the feasibility of preparing a European Atlas of Natural Radiation, in 2005 the Joint Research Centre (JRC) performed a survey of Rn monitoring efforts in European countries; it resulted in a colourful mosaic of national approaches with hardly comparable results due to differences in policies, data processing and mapping techniques.

In Prague in 2006, participants agreed on an indoor Rn map, based on measurements in ground floors of buildings. The data are aggregated into cells of size 10x10 km^2 on a common European grid. The cell data are then sent to the JRC, where they are collected and mapped. Despite the fact that 19 European countries already have contributed with their data, given the size and complications of the endeavour, the map is still incomplete.

We present the status of the map and discuss remaining issues, such as how to represent areas with very few data points and, as a follow-up project agreed upon in Oslo in 2008, how to come to a geogenic radon map.

Field Measurements on Unattached Fraction of Indoor Radon Progeny and its Dose Evaluation

Qiuju Guo[1], Lei Zhang[1], Lu Guo[1], Weihai Zhuo[2], Bing Shang[3]

[1] *State Key Laboratory of Nuclear Physics and Technology, School of Physics,, Peking University, Haidian District, Beijing, 100871, China*
[2] *Institute of Radiation Medicine, Fudan University, Shanghai,, 200032, China*
[3] *National Institute for Radiological Protection, Chinese Center for Disease Control and Prevention, Beijing, 100088, China*

qjguo@pku.edu.cn

The unattached fraction of indoor radon progeny is one of the most important factors working on radon exposure. For a precise dose evaluation and analysis on radon exposure, a pilot survey of field measurements on unattached fraction of radon progeny in real indoor environments were carried out by deployed a new type of portable, integrating monitor with etched track detector (CR-39). And then by using LUDEP, dose contribution of both unattached fraction and total radon progeny were calculated, respectively according to the field survey results.

The results showed that the unattached fraction varies from 8-23% in different indoor environments; accordingly its dose contribution to that of total radon progeny was calculated to be 36-62%.

The Influence of Radon Measurement Errors on the Uncertainties of Epidemiological Case-Control Studies

Michael Zhukovsky, Aleksandra Onishchenko, Anatoly Varaksin, Aleksey Vasilyev

Institute of Industrial Ecology UB RAS, Sophy kovalevskoy St., 20, Yekaterinburg, 620219, Russia

michael@ecko.uran.ru

In the case-control studies the uncertainties of dose-effect dependence as a rule is assessed only on the base of the quantity of peoples in the groups. The accuracy of radiation exposure measurements are supposed very high. The influence of typical measurement errors 30% on the uncertainties of radon case-control analysis is demonstrated on the examples both real studies conducted in Ural region and hypothetical case and control groups with the size from 50 – 100 to 500000 – 1000000 members. The modeling was conducted by Monte-Carlo technique for different kinds of measurement uncertainties distribution. The uncertainties of dose-effect dependence on the measurement errors are strongly depend on the size of group selection and for typical size of case group 500 and control group 1000 peoples the relative standard deviation is ∼0.5. Nevertheless for any size of groups the main reason of dose-effect assessment uncertainties is due to the quantity of peoples in case and control groups.

Radon-related index of municipalities

Ivana Fojtikova[1], Ivan Barnet[2], Miriam Marusiakova[1]

[1] *National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic*

[2] *Czech Geological Survey, Geologická 6, Prague, 15200, Czech Republic*

ivana.fojtikova@suro.cz

The determination of radon prone areas is usually based on indoor radon data and on the prognosis of the occurrence of houses exceeding the action level. However, the sample of houses in the survey must be representative and large enough, which is not easy to fulfill. Despite of this, the determination of localities with high radon risk is useful not only for planning of indoor radon surveys, but mainly for predicting the risk in newly built houses. There exist two more sources of data that can be used when assigning radon-related index to territories: soil gas radon measurements and gamma-dose rate maps, each having their own inaccuracies.

An test has been made to combine Czech indoor radon data, soil gas radon data and gamma-dose rate maps for the municipalities, where available. The radon-related index has been calculated by means of linear regression. The equations found can be used to predict radon risk of the municipalities where the data sets are not large enough.

Methods of measurement - devices, metrological aspects

posters

Calibration of Radon Monitors Using a NIST Radon Standard

M. Aitziane[1], F.Z. Abdelaziz[1], F. Bouchneb[1], M. Mezaguer[1], D. Imatoukene[1], Z. Mokrani-Lounis[1], M. Allab[2]

[1] *Dosimetrie des Rayonnements Ionisants, Centre de Recherche Nucléaire d'Alger, 2, Bd Frabtz Fanon, Algiers, Algeria*

[2] *Laboratoire de Sciences Nucléaires, Université des Sciences et de la Technologie Houari Boumediene Alger. Algérie*

aitzianemounir@yahoo.fr

In order to establish the national radon level according to the ICRP recommendations, radon levels should be estimated in different living environments (dwellings, workplaces, hospitals, ...). A particular attention should be given to the correctness of the radon concentration measurement devices in order to maintain their traceability to primary standard laboratory. Radon monitor systems have thus been calibrated using a NIST standard source which is considered as an important step in standardising radon measurement methods.

In this paper, we describe the system used in our laboratory for the calibration of different radon monitors such as Electret Ion Chamber (EIC), tracks detectors and AlphaGUARD continuous radon monitor. Preliminary radon concentration measurements have been performed in some locations at the Centre de Recherche Nucléaire d'Alger using the calibrated radon monitor systems. The deduced results have been compared to those obtained in a previous work.

A Chamber to Test the Response of Radon Detectors to Changing Enviromental Conditions

Alfonso Compagno, Aldo Parlato, Salvatore Rizzo, Elio Tomarchio

Dipartimento di Ingegneria Nucleare, Università degli Studi di Palermo, Viale delle Scienze - Parco d'Orleans - Ed. 6, Palermo, 90128, Italy

tomarchio@din.unipa.it

Radon risk assessment is carried out with accurate measurements with active or passive instrumentation. All radon detectors must be calibrated and tested using a radon chamber containing a known concentration of radon produced by specific sources of ^{226}Ra. Some of the chambers can also be used to test the response of detectors as a function of environmental conditions. In this case, it can be inferred a calibration curve with respect to changing of the parameter considered. For this aim, a new chamber radon was designed and realized to perform both calibration of instruments and to study the detector response in a large range of variation of the environmental parameters (pressure, 700 - 1100 mbar; temperature, 5-50 °C; humidity, 10-90%). The experiments conducted to study the influence of environmental parameters on the detector response, in terms of variation of radon concentration and equilibrium factor, have shown flexibility and ease of use of the chamber.

Concentrations of ^{222}Rn, ^{220}Rn and their Progenies Measured Inside a Karstic Cave by Using CR-39 and LR-115 II SSNTD and Resulting Dose to Speleologists

Jamal Ouguidi, M.A. Misdaq, M. Samodi, A. Chaib, A. Chaouqi

Nuclear Physics and Techniques Laboratory, Faculty of Sciences Semlalia, University Cadi Ayyad, My Abdelah-Semlalia, Marrakech, 40000, Morocco

j.ouguidi@ucam.ac.ma

Alpha-activities per unit volume due to ^{222}Rn, ^{220}Rn and their decay products were measured inside the atmosphere of a karstic cave where the dominant substance is calcium carbonate, precipitated in the form stalactites and stalagmites, by using both CR-39 and LR-115 II solid state nuclear track detectors (SSNTDs). The equilibrium factors between radon and its progeny and between thoron and its decay products were determined. The influence of the ventilation rate on the radon and thoron concentration inside the studied cave was investigated. Annual committed effective doses due to the ^{218}Po and ^{214}Po radon short-lived decay products from the inhalation of air by speleologists inside the studied cave were determined and compared to data obtained by using the ICRP publication 65 dose coefficient.

Determination of the Attached and Unattached Fractions of Short-Lived Radon Decay Products in Open Air by Using Solid State Nuclead Track Detectors and Resulting Radiation Doses to the Human Respiratory System

Jamal Ouguidi, Mohamed Amrane

Faculty of Sciences Semlalia, University Cadi Ayyad, My Abdelah-Semlalia, Marrakech, 40000, Morocco

j.ouguidi@ucam.ac.ma

We developed a model for determining the alpha and beta activities per unit volume of air due to radon (^{222}Rn), thoron (^{220}Rn) and their decay products attached and unattached to the aerosol in the open air at different locations in Morocco by using both CR-39 and LR-115 type II solid-state nuclear track detectors (SSNTDs). In addition, the percentage of the ^{218}Po, ^{214}Pb and ^{214}Po radionuclides attached to the aerosols and the unattached fraction f_j, for different values of the attachment rate were evaluated. The committed equivalent doses due to ^{218}Po and ^{214}Po radon short-lived progeny attached and unattached to the aerosol in the air were evaluated in different tissues of the respiratory tract of the members of the public from the inhalation of outdoor air.

Development of a New Thoron Progeny Detector Based on Alpha Track Detector and the Collection by an Electric Field

Lei Bi[1,2], Oliver Meisenberg[1], Jochen Tschiersch[1], Marek Wielunski[1], Junli Li[2], Bing Shang[3]

[1] *Helmholtz Zentrum München - German Research Center for Environmental Health, Institute of Radiation Protection, Germany*
[2] *Department of Engineering Physics, Tsinghua University, China*
[3] *National Institute for Radiological Protection, Chinese Center to Medical Response to Radiation Emergency, China*

bilei1983@gmail.com

The importance of thoron progeny for human exposure has been widely recognized in the past decades. Since no stable equilibrium factors were found between indoor thoron and its progeny, and the concentration of thoron progeny varies much with time, it is necessary to develop detectors for long term measurement that directly sample and detect thoron progeny. However, power supply of this kind of detectors has always been a problem. In this paper, a set of device that needs low power supply is introduced. A high voltage electric field was formed for the collection of charged aerosols attached by radon and thoron progeny. Since the highest energy of α particle emitted by thoron progeny is 8.77 MeV, while that of radon progeny is 7.68 MeV, impact from radon progeny can be eliminated with a shield of Al foil with appropriate thickness. Tests were made in an experimental house in Helmholtz-Mnchen to verify the universality under different conditions and to determine the efficiency.

Experimental Assessment of Long-term Radon Concentration Measurement Precision in Field Conditions

Carmela Carpentieri[1], Zora S. Zunic[2], Vinicio Carelli[3], Carlo Cordedda[3], Gianluca Ferrigno[1], Nenad Veselinovic[2], Peter Bossew[4], Tore Tollefsen[5], Olivera Cuknic[2], Zoran Vojinovic[2], Francesco Bochicchio[1]

[1] *Technology and Health, Italian National Institute of Health (ISS), Viale Regina Elena 299, Roma, 00161, Italy*
[2] *ECE Lab, Vinča Institute of Nuclear Sciences, Beograd, Serbia*
[3] *Safety and Environment, Telecom-Italia S.p.A, Roma, Italy*
[4] *German Federal Office for Radiation Protection (BfS), Berlin, Germany*
[5] *Institute for Environment and Sustainability, European Commission Joint Research Centre (JRC), Ispra, Italy*

carmela.carpentieri@iss.it

For surveys on long-term radon concentration in buildings it is important to evaluate the measurement precision in field conditions. To this end, within a survey underway in schools of southern Serbia, paired detectors were exposed in each room in order to experimentally assess measurement precision.

Paired passive devices (containing CR-39 detectors) were exposed for two consecutive 6-month periods. Moreover, first period CR-39s were readout by a different measurement system of that used for the second period ones, which allows evaluating the precision of both systems.

The median of the coefficient of variation (CV) of the exposure measured by the paired devices in 243 rooms of 125 different schools was 8% and 4% for the two systems, with track count repeatability (median) of 4% and 1%, respectively.

This *in field* precision will be compared with precision obtained during calibration at different exposure levels and with measured variation of radon concentration within the 125 schools.

Indoor Radon Concentration Levels in Semi-Desert, Semi-Tropical and Tropical Regions in Mexico

Guillermo Espinosa[1*], Richard B. Gammage[2]

[1] *Departamento de Fisica Experimental, Instituto de Fisica - Universidad Nacional Autonoma de Mexico, Circuito de la Investigacion Cientifica - Ciudad Universitaria, Mexico D.F., 05420, Mexico*

[2] *ORNL Retired, Oak Ridge National Laboratory, United States*

espinosa@fisica.unam.mx

The regional climate on semi-desert, semi-tropical and tropical places and therefore the ventilation habits of the population are two very important factors on the indoor radon levels in dwellings and houses. In this work, the indoor radon levels along the Mexican Country (1'972,550 Km^2) divided in three climate regions is presented.

Low indoor radon levels, between 37 $Bq{\cdot}m^{-3}$ and 179 $Bq{\cdot}m^{-3}$, were found in each of the three climate regions. The common factors in these three regions are the annual average temperature, between 15°C to 28°C, and ventilation habits of the population. On the other hand, the geological characteristics, the building construction materials, architectonic styles, seismicity, and hydrological characteristic are different in each region.

* *PAPIIT-DGAPA-UNAM project 1N101910-3.*

Quality Assurance of Radon Measurements based on CR-39 Detectors within the Framework of Laboratory Requirements for ISO

Gabriele Pratesi, Ilaria Peroni, Silvia Bucci, Sandra Gambi, Fabio Cioni, Riccardo Magnanelli

Florence Department, ARPAT, via Ponte alle Mosse 211, 50144 Florence, Italy

s.bucci@arpat.toscana.it

In 2006 ARPAT, Environmental Protection Agency - Tuscany Region, has obtained, first in Italy, the accreditation based on ISO/IEC 17025 "General Requirements for the Competence of Testing and Calibration Laboratories"for the method "Measurement of the Indoor Radon concentration in air by SSNT CR-39 detectors".

The method is based on a track analysis system (TASL) of CR-39 detector chemically etched in a NaOH thermal bath.

In this work we describe the quality assurance and quality control system that was set up in order to accomplish the technical requirements for laboratory accreditation for radon measurements with SSNT CR-39 detectors.

In particular the following points will be discussed in detail: geeral procedure for the validation of method, estimation of uncertainty of measurement with laboratory and in field ripetibility, calibration up to high exposure values and measurmentes traceability, quality control of equipment and of data.

Radon Measurement and Mitigation Action at Eni Historical Museum (Pomezia - Roma)

G. Scarpanti[1], P. Sala[1], R. Fresca Fantoni[1], S. Funiciello[2], L. Nardi[2], S. Penzo[3], M. Calamosca[3]

[1] *Radiation Protection Department - RADI, ENI - Exploration & Production Division, Via Emilia, 1, San Donato Milanese, Milano, Italy*

[2] *ENI - Exploration & Production Division, Corporate, Piazzale Enrico Mattei, Roma, Italy*

[3] *ENEA - IRP, - Montecuccolino, Via dei Colli. 16, Bologna, Italy*

giovanni.scarpanti@eni.it

The present work concerns the radon survey conducted at the Eni Historical Archives, located in Pomezia (Roma), in a collaborative frame between Eni and ENEA Institutes of Radioprotection aimed to evaluate the radon exposure in workplaces. The building is located in a geological prone area, characterized by the presence of *Pozzolane rosse* with high ^{226}Ra activity concentrations.

Continuous (Alphaguard) and integrated (Alpha Track Detectors, ENEA holder and CR-39) measurements were carried out. Preliminary results put in evidence high values of radon mean concentration (maximum value: 1183 Bq/m^3, average value: 496 Bq/m^3).

Mitigation actions, have been carried out by increasing the air change rate of the ventilation system, solving the room depressurization. Preliminary results point out that this remedial action was able to lower the radon concentration by a reduction factor of 4, both for peak and mean values.

Radon, Thoron and Their Decay Products Measured Inside Two Moroccan Thermal Spas and Resulting Radiation Doses to the Bathers and Workers

Jamal Ouguidi, Mounaim Ghilane

Faculty of Sciences Semlalia, University Cadi Ayyad, My Abdelah-Semlalia, Marrakech, 40000, Morocco

j.ouguidi@ucam.ac.ma

Radon is a natural radioactive gas generated from the ^{226}Ra alpha-decay. It is a noble gas with 3.82 days half-life and high water solubility. In the present study, radon, thoron, and their decay products were measured in different locations of two Moroccan thermal spas by using CR-39 and LR-115 II solid state nuclear track detectors (SSNTDs). The equilibrium factors between radon and its progeny and between thoron and its decay products were evaluated. The committed effective doses due to the ^{218}Po and ^{214}Po radon short-lived decay products from the inhalation of air by bathers and workers inside the two thermal spas were determined.

The Results of Outdoor Radon Monitoring in Bratislava and Nováky

Monika Müllerova, Karol Holy, Martin Bulko

Faculty of Mathematics, Physics and Informatics, Comenius University, Mlýnská dolina, Bratislava, 841 04, Slovakia

mullerova@fmph.uniba.sk

The measurements of the radon activity concentration were realized in two localities of Slovakia. The first one is in the campus of the Comenius University (CU) in Bratislava, where the radon has been monitored since 1991. The second area is situated in Nováky, city in the middle of Slovakia, about 150 km distant from Bratislava where the radon was monitored one year. The orography of these localities is different. The radon activity concentration was measured continuously by large volume scintillation chambers. The outdoor air was sucked at the height of 1.5 m above the Earths surface. The time courses of radon activity concentration in both localities have a similar character. The correlation coefficients between radon activity concentration in CU Bratislava and Nováky was quite high ($R^2 \sim 0.45$). However, the radon activity concentrations in Nováky were found out about two times higher (~ 11 Bq.m^{-3}) than in Bratislava.

Setting up a Callibration System for Determination of Dissolved Radon in Water Using SSNTDs

Mehran Taheri[1], Mohammad Reza Taghdir[2]

[1] *National Radiation Protection Department, Iranian Nuclear Regulatory Authority, Iran*

[2] *Chemical Engineering Department, Faculty of Technology, University of Tehran, Iran*

mmtaheri@yahoo.com

A prototype passive integrating radon-in-water chamber based on the diffusion principle and using etch track detectors has been developed for measurement of the radon concentration in water and a system has been set up to calibrate it.

The method is based on exposing the PC detector due to radon emanation from water into a floating chamber. The calibration system consists of two water vessels and a flow-through radon standard source. This method generates the radon-in-water standard solutions with various radon concentrations applicable for calibration of continuous long-term radon-in-water measurement systems. Some important parameters which may affect on calibration characteristics, e.g. the effect of radon-in-air flow rate bubbled through the water to attain the state of equilibrium, were investigated.

The main objectives of the work are: 1) to develop and optimize a straightforward and easy-to-handle experimental setup for the on-site determination of radon-in-water concentrations and, 2) to apply a low running cost calibration system which is perfect for calibration and quality control of measuring systems.

The results show that the calibration factor is equal to 125.66 $(mBql^{-1})\cdot(track^{-1}cm^2).(day)$ and the detection limit is about 0.096 $Bq\cdot l^{-1}$ for exposure time of 30 days.

Study on the Influence Factors about the Soil Radon Measurement

Yang Yu-hua, Liu Yan-bing, Jia Yu-xin

Guangdong prevention & Treatment Center for Occupational Diseases, 68 haikang St, Xinggang Rd,W.,Haizhu district, Guangzhou, 510300, China

yangyhgd@163.com

Objective: To explore relevant factors about the soil radon measurement and provide gist of formulating correct measure method by studying the way of the soil radon measurement.

Method: Deflation-ionization room standard is adopted.

Results: The concentration of soil radon enhanced with the sample's volume added, it also augmented with the measure depth increased in certain degree; The concentration of soil radon changes little when sample's depth is above 60cm; The time of deflation has no obvious influence on the concentration of soil radon, but microwave show serious effect on it; The results will be lowered when the desiccant is humidified, raining has the same affection on it; Plant has some impact on it.

Conclusion: The measure results will be affected by microwave, oscillate and plant. Sample's volume and depth, soil's humidity can influence it too. The result's veracity can be guaranteed by choosing appropriate sample and measure condition.

A Survey of ^{222}Rn in Drinking Water in Mexico City

Guillermo Espinosa[1*], Jose-Ignacio Golzarri[1], Blanca Zendejas-Leal[2], Carlos Vazquez-Lopez[2]

[1] *Departamento de Fisica Experimental, Instituto de Fisica - Universidad Nacional Autonoma de Mexico, Circuito de la Investigacion Cientifica - Ciudad Universitaria, Mexico D.F., 04520, Mexico*

[2] *Departamento de Fisica, Centro de Investigacion y de Estudios Avanzados del IPN, Ave. IPN 2508., Mexico, D.F., 07360, Mexico*

espinosa@fisica.unam.mx

In Mexico City there are more than 22 millions of inhabitants, exposed to drinking water. The local epidemiological authorities recognized that exposure to radon from drinking water is a potential health hazard, as has been considered worldwide.

The United States Environmental Protection Agency has proposed a limit of 11.1 Bq/L for the radon level in drinking water. In Mexico a maximum contamination level (MCL) of radon in drinking water has not yet even considered. In this work, a radon-222 study of drinking water in Mexico City has revealed a range of concentrations from 0.025 Bq/L to 15.0 Bq/L. Radon-222 was measured using a portable degassing system associated with an AlphaGUARD measuring system.

* *Instituto de Ciencia y Tecnología del Distrito Federal, México and PAPIIT-DGAPA-UNAM Project 1N101910.*

Toward a Standard Protocol for Short Term Active Measurements: Radon Risk Assessment in One Week

Paola Canonica, Loris Ghirlanda, Tiziano Teruzzi, Claudio Valsangiacomo

Department of Environment, Construction and Design, University of Applied Sciences and Arts of Southern Switzerland, Trevano, Canobbio - Lugano, 6952, Switzerland

paola.canonica@supsi.ch

General recommendations given by public authorities to perform radon tests refer to long term passive measurements on the lowest level of the home that could be used for living. In such a way, radon level fluctuations on a daily, weekly, and monthly basis are averaged over a long period. The results of such measurements, being a simple average radon concentration in Bq or pCi per cubic meter, are easy to understand and to compare to reference values for both public officials and for any other individual (owner, user) requesting the measurement. However, under some circumstances (real estate transactions requiring immediate results, evaluation of radon mitigation, etc.), short term active measurements are the only viable way to go. Unfortunately no generally agreed standard operating procedure is available. We propose a standard protocol for short term active measurements in 7 days. A comparison with passive long term measurements (3 months) performed according to Swiss regulations is presented and variability of both measurements and their potential for delivering information on radon risk assessment are discussed.

Radon - information carrier, radonometry, radon as a tracer gas

oral presentaions

Radon in Earthquake Prediction Research

Harry Friedmann

Nuclear Physics, University Vienna, Faculty of Physics, Währingerstr. 17, Vienna, A 1090, Austria

harry.friedmann@univie.ac.at

The observation of anomalies in the radon concentration in soil gas and ground water before earthquakes initiated systematic investigations on earthquake precursor phenomena in the radon concentration of groundwater and soil gas. The question what is needed for a meaningful earthquake prediction as well as what types of precursory effects can be expected is shortly discussed. The basic ideas of the dilatancy theory are presented which in principle can explain the occurrence of earthquake forerunners. The reasons for radon anomalies in soil gas and in ground water are clarified and a possible classification of radon anomalies is given.

Indoor and Soil Gas Radon Simultaneous Measurements for the Purpose of Detail Analysis of Radon Entry Pathways into Houses

Ales Fronka

Radon Expert Group, National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic

ales.fronka@suro.cz

The detailed knowledge of radon transport mechanisms from the subsoil into the indoor environment is absolutely essential for the correct interpretation of results of short term indoor radon measurements and for proper design of radon mitigation systems. In addition, the radon transport behavior is closely associated with the physical properties of engineering structures and the appropriate part of subsoil. Radon transfer factor time variations have been studied based on simultaneous continuous indoor and soil gas radon measurements within the framework of complex radon diagnosis of individual buildings. In this context, the key influencing factors have been identified and analyzed in order to provide satisfactory explanation of radon entry variations under different measurement conditions. Moreover, a new significant manner of radon entry pathway into the indoor environment has been identified and will be discussed in detail.

Variation of Natural Radon Flux over the Earth's Surface: a 2010 Update

Stephen Schery[1,2]

[1] *Department of Physics and Geophysical Research Center, New Mexico Tech, 801 Leroy Place, Socorro, NM 87801, 87801, United States*
[2] *Experimental Aerophysics Branch, NASA/Ames, Ms 260-1, Moffett Field, 94035, United States*

schery@nmt.edu

Natural radon flux over the entire earth's surface is a time-honored but still challenging subject. Information on the distribution of radon flux density over the earth's surface is important for global atmospheric modeling applications but also provides insight into where high indoor building radon concentrations might be expected. In the last few years, there has been considerable progress in measuring and modeling radon flux density for Europe, China, and even the oceans. Regional variations by at least a factor of three are common. But there has been less new information for the southern hemisphere. Variation of radon flux density over many parts of Africa and South America remains poorly known. A major impediment for the southern hemisphere is the lack of information on surface radium concentration or surface gamma ray flux comparable to that available for many parts of the northern hemisphere. Such information is important as an input into models of radon flux density which are commonly used to generate radon flux density predictions for the globe.

Soil Gas Radon Measurements in a Region of the Bohemian Masif: Investigations in the Framework of an Ausrian Pilot Study

Andreas Baumgartner[1], Claudia Seidel[1], Franz Josef Maringer[1,2], Wolfgang Ringer[3], Joachim Gräser[3], Harry Friedmann[4], Heribert Kaineder[5]

[1] *BOKU - University of Natural Resources and Applied Life Science, LLC-Laboratory Arsenal, Faradaygasse 3, Arsenal 214, Vienna, 1030, Austria*
[2] *BEV - Federal Office of Metrology and Surveying, Arltgasse 35, Vienna, 1160, Austria*
[3] *AGES - Austrian Agency for Health and Food Safety, Radioecology and Radon, Derfflingerstrasse 2, Linz, 4020, Austria*
[4] *University of Vienna, Nuclear Physics, Währinger Strasse 17, Vienna, 1090, Austria*
[5] *Federal Government of Upper Austria, Environment, Kärnterstrasse 10-12, Linz, 4020, Austria*

claudia.seidel@boku.ac.at

In the framework of a pilot study soil gas radon measurements are carried out in three Upper Austrian municipalities which are characterized by a high radon potential. On the basis of geological maps 60 measuring sites – well distributed over the region – were selected. Additionally to the measurements of radon activity concentration in soil, the permeability of soil is determined and at various sites soil samples are taken, which are analysed by gamma spectrometry. Moreover, long-term measurements are carried out to study the long-term behaviour of radon activity concentration in soil, the influence of meteorological parameters and seasonal variations. Finally the collected data are correlated with the results of long-term indoor radon measurements and geological data. First results of this ongoing study are presented and discussed in this paper.

Determination of the Diffusion Coefficient and Solubility of Radon in Plastics

Dobromir Pressyanov, Strahil Georgiev, Ivelina Dimitrova, Krasimir Mitev, Tatjana Boshkova

Faculty of Physics, University of Sofia "St. Kliment Ohridski", 5 James Bourchier Blvd., Sofia, 1164, Bulgaria

pressyan@phys.uni-sofia.bg

A method for determination of the diffusion coefficient and the solubility of radon in plastics is described. The method is based on the absorption and desorption of radon in plastics. Firstly, plastic specimens are exposed for controlled time to referent ^{222}Rn concentrations. After exposure, the activity of the specimens is followed by HPGe gamma spectrometry. Using the mathematical algorithm described in this report, and the decrease of activity as a function of time, the diffusion coefficient can be determined. In addition, if the referent ^{222}Rn concentration during the exposure is known, the solubility of radon can be determined. The algorithm has been experimentally applied for different plastics. The results show, that this approach allows the specified quantities to be determined with a rather high accuracy – depending on the quality of the counting equipment, it can be better than 10%.

International Comparison of Radon Diffusion Coefficient Measurement in Polyethylene Foil

Katerina Rovenska[1], Martin Jiranek[2]

[1] *Radon Expert Group, National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic*

[2] *Department of Building Structures, Czech Technical University, Faculty of Civil Engineering, Thákurova 7, Prague, 16629, Czech Republic*

katerina.rovenska@suro.cz

Radon diffusion coefficient is a material parameter which is usually used in the radon mitigation measures design. There are different approaches used for radon diffusion coefficient measurement and assessment. The International comparison measurement which was jointly organized by National Radiation Protection Institute and Faculty of Civil Engineering CTU Prague in 2009 and 2010 has registered 11 laboratories from all over the world. Three sets of samples of polyethylene damp-proof membranes were sent to these laboratories for measurement. Up to day the organizers received only five sets of results. The results showed a great variability among laboratories involved.

Radon Diffusion Through Various Building Materials

Natasa Todorovic[1], Selena Grujic[2], Uranija Kozmidis-Luburic[2], Istvan Bikit[1], Dusan Mrda[1], Sofija Forkapic[1]

[1] *Department of Physics, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovica 4, Novi Sad, 21000, Serbia*
[2] *Faculty of Technical Sciences, Trg Dositeja Obradovica 4, Nocvi Sad, 21000, Serbia*

natasa.todorovic@df.uns.ac.rs

Since people most of the time spent inside the buildings it is of great importance to analyze the radon diffusion through different types of materials, in order to prevent the increase of its concentration in the interior of buildings. We have prepared simple experimental setup to determine radon diffusion coefficients in laboratory conditions. The paper examined six different types of materials used in construction, mainly in the insulating purposes, in order to determine the material with lowest value of radon diffusion coefficient. The combination of appropriate type and thickness of material is also investigated. The lowest value of diffusion coefficient of $9(4).10^{-11}$ m^2/s was calculated for the aluminum sheet. Obtained results are compared with other results published before.

Noble Gases, Chemical Tracers And Detection Of Underground Nuclear Explosions

Charles R. Carrigan

Lawrence Livermore National Laboratory, Livermore, CA 94550, United States

carrigan1@llnl.gov

Underground nuclear explosions (UNE) produce trace amounts of the short-lived noble gases ^{113}Xe and ^{37}Ar at their detonation points. Several different gas transport mechanisms can move these gases to the surface where their detection can be a highly distinctive indicator of a UNE. This transport behavior was demonstrated by the 1993 "Nonproliferation Experiment", a non-nuclear explosion representing an analog to a UNE. Tracer gases were released by the detonation and were transported along faults and fractures to the surface over a period of a year where they were detected at sampling stations. The main transport mode was atmospheric pumping, which is many times more effective than diffusion. Had the gases been from a UNE, detection would have been possible by subsurface gas sampling as part of the Comprehensive Nuclear-Test-Ban Treaty On-Site Inspection (OSI) monitoring protocol. The potential role of radon measurements in support of subsurface sampling during an OSI is considered.

Signifiance of Independent Radon Entry Rate and Air Exchange Rate Assessment for the Purpose of Radon Mitigation Effectivness Proper Evaluation: Case Study

Ales Fronka[1], Ladislav Moucka[1], Karel Jilek[1], Marek Brabec[2,3]

[1] *Radon Expert Group, National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic*

[2] *Institute of Computer Science, Department of Nonlinear Modeling, Academy of Sciences of the Czech Republic, Vodarenskou vezi 2, Prague, 18207, Czech Republic*

[3] *Department of Biostatistics and Informatics, National Institute of Public Health, Srobarova 48, Prague, 10000, Czech Republic*

ales.fronka@suro.cz

Two new single-family houses, identified as insufficient with regard to existing radon barrier efficiency based on the short term screening measurement have been selected for further examination. A complex set of radon diagnosis procedures have been applied in order to localize and quantify radon entry pathways into the indoor environment. Independent assessment of radon entry rate and air exchange rate has been carried out using the continuous indoor radon measurement and a specific tracer gas application. Simultaneous assessment of these key determining factors has turned out to be absolutely crucial in the context of major cause identification of elevated indoor radon level occurrence. Individual partial results of radon diagnosis in given cases and the final evaluation report will be presented and discussed in detail.

Radon Levels in Ambient Air as Accumulation Indicators of Air Pollution

Anna Benedetta Somigliana[1], Donata Lerda[2]

[1] *Dipartment of Milan, ARPA Lombardia, Via Juvara, 22, Milano, 20129, Italy*
[2] *EC-JRC-IRMM, Retieseweg 111, Geel, 2440, Belgium*

a.somigliana@arpalombardia.it

In the Po Valley atmospheric stability episodes often depend on thermal inversion phenomena. The height of the atmospheric mixed layer (Hmix) decreases leading to increased concentrations of air pollutants such as PM10, benzene, aromatic hydrocarbon (AH)... Hmix can be considered proportional to the Radon decay products. Measurements of Radon quantity through its alpha particles activity and of air pollutant quantities through other means were carried out from feb-2000 to jul-2001 in a type B urban location in the city of Milan. The results were processed taking into account variables like precipitation and wind. A good correlation was obtained for benzene and radon both in winter and in summer. About PM10 and radon, the correlation is better in winter than in summer because of the bigger importance of the secondary contribution to particulate matter. This study confirms the importance of meteorological conditions on air quality particularly in urban areas.

Simultaneous Measurements of the Atmospheric Fast Ions and Indoor Radon Concentration in the Underground Low-lewel Laboboratory in Belgrade, Serbia

Vladimir Udovičić, Predrag Kolarž, Dejan Joković, Aleksandar Dragić, Radomir Banjanać, Bratislav Marinković, Ivan Aničin

Institute of Physics, Pregrevica 118, Belgrade, 11080, Serbia

udovicic@ipb.ac.rs

Simultaneous measurements of the fast atmospheric ions and indoor radon concentration were done in the different experimental conditions due to get precise relation between those two parameters. The measurements were performed in the underground and ground level laboratory in the Institute of Physics in Belgrade, Serbia. In this work we are analyzed the obtained results and give the suggestions for the future investigations.

Air Ions to Radon Transfer

Predrag Kolarž[1], Bratislav Marinković[1], Dusan Filipović[2]

[1] *Laboratory for Atomic Collision Processes, Institute of Physics, Pregrevica 118, Belgrade, 11080, Serbia*

[2] *Faculty of Physics, Studentski trg 12, Belgrade, 11000, Serbia*

kolarz@ipb.ac.rs

"Air ions" are all charged airborne particles which have electrical mobility. In troposphere, they are continually created by natural sources such as cosmic rays, radioactive minerals from the ground and radioactive decay of noble gas radon in the air. Diurnal variation in air ion concentration is subjected to radon concentration change. Air-ion and radon concentrations in various surroundings such as outdoor and indoor space, underground objects and residential buildings were simultaneously measured using Cylindrical Detector of Air ions (CDI-06) made in Institute of Physics, Belgrade and RAD7 radon detector made by Durridge Company, USA. The results have shown high correlation factor ($r>0.7$) between positive air-ions and radon in indoor measurements. The measuring concept of the air-ion detectors provides "real time" results and thus continuous tracking of Rn variations indoors is possible using air ions to radon transfer coefficient.

Estimates of the Annual Average Indoor Radon Concentration in Telecí in the Czech Republic

Miriam Marusiakova, Jiri Hulka

National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic

miriam.marusiakova@suro.cz

Radon and its progeny in dwellings is responsible for the majority of the total radiation dose among the general population. The primary source of radon in buildings is from the underlying soil and bedrock. Other sources are building materials and the water supply. Radon concentrations in a building can vary considerably during the daytime, from day to day, during the seasons.

The value of annual average radon level in a building is important in order to estimate the effective dose to inhabitants. However, it is not always possible to measure the radon concentrations throughout the whole year. Thus estimates based on short-term continuous measurements are suggested.

We analyse hourly radon measurements obtained from one uninhabited rural house in Teleci in the Czech Republic during one year. We discuss the behaviour of the radon concentration with time and its relationship to the meteorological variables. Further we discuss various estimates of the annual mean radon concentration.

Radon Time Series Analysis in the Underground Low-Level Laboratory in Belgrade, Serbia

Vladimir Udovičić, Ivan Aničin, Dejan Joković, Aleksandar Dragić, Radomir Banjanać, Bojana Grabez, Nikola Veselinović

Low-Background Laboratory for Nuclear Physics, Institute of Physics, Pregrevica 118, Belgrade, 11080, Serbia

udovicic@ipb.ac.rs

Measurements of radon concentration in the underground low-level laboratory in Belgrade, Serbia with a discrete sampling (T=2 h) have been performed. From July, 2008 to July, 2010 the time series analysis are carried out. Also, the simultaneous measurements of meteorological parameters (temperature, atmospheric pressure and relative humidity) in the laboratory were done. The analysis have emphasized that the simultaneous monitoring of these parameters shows the correlation between temporal variations of radon concentration and meteorological parameters. Moreover, the radon time series analysis has been used to study possible correlation between anomal behavior of radon concentration and local seismicity.

Comparison of Results of Methods to Determine Concentrations of Unattached and Attached Radon Progeny using the Inversion of the Jacobi-Porstendörfer Room Model

Josef Thomas, Karel Jilek

National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic

josef.thomas@suro.cz

So far the method of measuring the free and attached radon decay products in air is under development. Several examples are given to show detailed inconsistencies of results obtained in three metrological laboratories (AMC PŁ^{TM}Ăbram, PTB Braunschweig, NRPI Praha). The method of inversion of the measured data using the Jacobi-Porstendörfer room model (inversion results in estimation of parameters of this model, i.e. the coefficients of attachment of decay products on aerosols (X), on surfaces (q_f and q_a) and the recoiled fraction of RaA (R)), gives new opportunity to examine the causes of these detailed inconsistencies, e.g. by means of reassessment of the measured concentrations of RaA due to deficient in homogeneousness.

Radon in Soil Gas Versus Radon Flow in Characterization of Uranium Tailing Sities

Mykhailo Buzynnyy[1], Tatiana Lavrova[2], Maxim Romanenko[1], Victor Sakhno[1]

[1] *Radiation Hygiene, SE "The Marzeev Institute of Hygiene and Medical Ecology", 50, Popudrenko str., Kiev, 02094, Ukraine*
[2] *Ukrainian Hydrometeorology Institute, 37 Nauky ave., Kiev, Ukraine, 03650*

mbuz@ukr.net

Uranium tailings sites are wide scale sources of radon. Radon flow through soil (cover) surface depends on radium concentration in tailing, tailings depth and its permeability, presence and quality of cover. Our approach includes both radon in soil gas and radon flow (exhalation) measurements to allow characterization of each site studied. We use measurement methods based on liquid scintillation counting to cover wide range of measured characteristics: radon in sol gas 0.1 kBq/m^3 – 10 MBq/m^3, radon flow – 0.1 mBq/m^2/c – 200 Bq/m^2/c.

All sites studied could be characterized as: natural soils (NS) with low radon penetration, NS with medium and high radon penetration, tailings of medium and high activity with medium and high radon penetration and tailings with perfect cover and low radon penetration.

Radon in Soil Gas Variation on Pechersk Polygon in Kiev

Mykhailo Buzynnyy[1], Pedro Didenko[2], Mykola Makarenko[3], Maxim Romanenko[1]

[1] *Radiation Hygiene, SE "The Marzeev Institute of Hygiene and Medical Ecology", 50, Popudrenko str., Kiev, 02094, Ukraine*
[2] *Institute of Geochemistry of Environment NAS of Ukraine, 34a, Academician Palladin ave., Kiev, Ukraine*
[3] *SE "Kirovgelogia", 8/9 Kikvidze str. Kiev, Ukraine*

mbuz@ukr.net

Radon in soil gas variation depends on weather condition: atmosphere temperature and pressure. We have find contrast spatial distribution radon in soil gas in Kiev in our polygon site.

We performed long time measurements (18 month) of radon in soil gas aiming studying site specific peculiarities: two measurements per month for two places each of both low and high radon activity. Radon measurement in soil air was performed using modern method based on liquid scintillation counting [1]. Air samples were collected using small diameter pipe at depth of 0.8 m. Glass bubbler filed with liquid scintillation cocktail based on toluene was used as a trap.

We find well defined site specific radon variation corresponding to change of atmosphere temperature. Contrast radon dependence corresponding to atmosphere pressure is seen when considering warm period, T>3-4 °C.

References

[1] Buzinny M. LSC Based Approach for Radon in Soil Gas Measurement / M. Buzinny, V. Sakhno, M. Romanchenko // LSC 2008: Proc. of the Int. Conf. on Advances in Liquid Scintillation Spectrometry, Davos, Switzerland, May 25-30, 2008. [Eds. J.Eikenberg, M. Jagi, and H. Beer]. 2009. - Tucson: Radiocarbon. - **P**. 7-11.

The Pilot Study of Dependence of Radon Concentration on the Tectonic Structures using Simple Geophysical Methods

Lenka Thinova[1], Ales Fronka[2], Katerina Rovenska[1,2]

[1] *Department of Dosimetry and Application of Ionizing Radiation, Faculty of Nuclear Sciences and Physical Engineering Czech Technical University of Prague, Brehova 7, Prague 1, 11000, Czech Republic*

[2] *Radon Expert Group, National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic*

thinova@fjfi.cvut.cz

The high variation of the radon concentration in the soil gas on the building sites is well known phenomenon. Sometimes the concentration may vary of more then two orders of magnitude. The tectonic structure of the bedrock is one of the reasons which influences the strength of the radon supply. The simple geophysical method ARES (Automatic Resistivity System - main unit with standard accessories, the multi-electrode cable sections MCS5 - 8 electrodes / 5m spacing) in different modes (Schlumberger, Dipole-Dipole and Pole-Dipole arrays) was used for in situ tectonic structure determination. Radon concentration in the soil gas was measured in the same network like the resistivity. Measurement of radon was also followed up by the soil permeability measurement. The behavior of radon concentration in soil gas was correlated with the found tectonic inhomogeneities. This pilot study opened new questions for next analysis.

CFD Modelling of Thoron and Thoron Progeny in the Indoor Environment

Govert de With, Peter de Jong

Radiation and Environment, Nuclear Research and consultancy Group (NRG), Utrechtseweg 310, Arnhem, 6800 ES, Netherlands

G.deWith@nrg.eu

Thoron (^{220}Rn) exhalation from building materials has become increasingly recognised as a potential source for radiation exposure in domestic houses. However, contrary to radon, little is known about the exposure to thoron. The purpose of this study is to estimate the concentration of thoron and its progeny products in a typical Dutch living room using Computational Fluid Dynamics (CFD). The predicted thoron concentration is approximately 9 $Bq \cdot m^{-3}$ using a best possible estimate of 14 $Bq \cdot s^{-1}$ for the thoron exhalation from building materials. The thoron exhalation is derived theoretically and is based on measured radon exhalation rates of the most commonly used building materials in the Netherlands. The concentration varies from 15 $Bq \cdot m^{-3}$ near the building materials to 2.7 $Bq \cdot m^{-3}$ in the centre of the living room. The mean effective dose from thoron progeny is estimated at 0.09 $mSv \cdot y^{-1}$, with a total dose from radon and thoron of 0.38 $mSv \cdot y^{-1}$.

Airborne Natural Radioactivity in the Uranium Mine Rožná I

Petr Otahal, Ivo Burian

Nuclear Department, National Institue for Nuclear, Chemical and Biological Protection, v.v.i., Kamenna 71, Milin, 26231, Czech Republic

otahal@sujchbo.cz

The concentration of Radon-222, its progenies and long-lived radionuclides as well as aerosol particle size distribution were measured in the last uranium mine in the Czech Republic Rožná I. The measurements were performed in two typical underground workplaces (in the forefield, at the filling of corf) and in one workplace in the crushing plant. Radon-222 concentration varied from 0.3 to 11 kBq in the underground workplaces. The value of equilibrium factor F in the underground atmosphere was in the range from 0.03 to 0.17. The size distribution of long-lived radionuclides deposited on aerosol particles was determined by help of Andersen cascade impactor. The total concentration of long-lived radionuclides which emitted the alpha particles was in the interval from 0.01 to 0.35 $Bq \cdot m^{-3}$. The research was supported by the grand SONS within the project SUJ200402.

Elevated Radon Levels at the Niska Banja Spa

Jovana Nikolov, Natasa Todorovic, Sofija Forkapic, Dusan Mrda, Istvan Bikit

Department of Physics, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovica 4, Novi Sad, 21000, Serbia

jovana.nikolov@df.uns.ac.rs

Niska Banja spa is a health resort in South-East of Serbia well-known by elevated levels of radon. Indoor radon and radon in water concentration measurements in thermal pools and therapy rooms in the spa are presented. Occupational dose rates for medical staff were calculated and discussed. The maximal radon concentration of (22900±567) Bq/m^3 was measured in the basement of hotel-dispensary "Radon". This hotel is settled on the "bigar" rock with high content of ^{226}Ra. The gamma spectrometry measurements of soil, rock and therapy mud are also presented.

Radon - information carrier, radonometry, radon as a tracer gas

posters

Caves as Recent Geofactors Observatories (the Western Carpathians and Bohemian Massif)

Lenka Thinova[2], Milos Briestensky[1], Josef Stemberk[1], Matt Rowberry[1]

[1] *Engineering geology, Institute of the rock structure and mechanics, V Holešovičkách 41, Prague, 18209, Czech Republic*
[2] *Department of Dosimetry and Application of Ionizing Radiation, Faculty of Nuclear Sciences and Physical Engineering, Brehova 7, Prague, 115 19, Czech Republic*

briestensky@irsm.cas.cz

During last years, many underground spaces like caves and deep mines were established to monitor recent tectonics in Bohemian massif and in the Western Carpathians. Moreover, current radon gas monitoring has been performed in three of the caves too. Observed radon concentration showed diurnal, seasonal as well as yearly variations. We have registered significant correlation with external temperature, whose pattern is generaly thought as a result of air movements due to differences between internal and varying external temperatures. The same seasonal effects were registered in results of active fault displacements, resulting in peak-to-peak massif dilatation amplitude affecting fault displacement trends. There was registered significant decrease of the amplitude due to depth as well. On the other hand, some high variabilities of radon concentration as well as fault displacement events occurred during the study.

Radon Concentration Trend in a Tourist Cave (NE Italy)

Massimo Garavaglia[1], Concettina Giovani[1], Luca Piccin[1], Franco Cucchi[2], Luca Zini[2]

[1] *Environmental Physics, Friuli Venezia Giulia Regional Agency for Environmental Protection, Italy, via Tavagnacco 91, Udine, I-33100, Italy*
[2] *Geosciences Department, Trieste University, via Weiss 2, Trieste, I-34127, Italy*

massimo.garavaglia@arpa.fvg.it

Elevated concentration of Rn-222 have been recorded in many limestone caves throughout the world. In some cases it represents an impact and risk for who works in the caves and it is necessary to estimated dose to workers. In any case it is of interest to study spatial distribution and time variation of radon concentration inside the caves. This paper concerns a study lasted over than one year in a very large tourist cave near Trieste (NE Italy). After a first study that excluded risk for workers and visitors, a more detailed study was performed to analyze the distribution of radon concentrations in the different part of the cave and to observe the trend during the year. Different kind of measurements were performed: short measurement by E-Perm electrects to study radon concentrations distribution in the cave and long term measurements by active instruments RAD-7 to study radon concentration trend along the year and eventually correlation of radon concentration with internal and external temperature of the cave and other parameters. Radon concentrations of over than 20000 Bq/m3 were measured during summer in a non tourist part of the cave. In the same site radon concentrations lower than 100 Bq/m^3 were recorded during colder seasons. In this paper the first results of this study are reported.

Radon Exchange Dynamics in a Karst System Investigated by Radon Continuous Measurements in Water

Guido Peano[1], Bartolomeo Vigna[1,2], Ezechiele Villavecchia[1], Giovanni Agnesod[3]

[1] *Laboratorio Carsologico Sotterraneo di Bossea, Frabosa Soprana (CN), 12082, Italy*

[2] *Politechnico di Torino, Dipartimento DITAG, Italy*

[3] *ARPA Valle d'Aosta, Loc. Grande Charriere, 44, Saint-Christophe (AO), 11020, Italy*

g.agnesod@arpa.vda.it

The Underground Karst Lab of Bossea cave started in 2008 a research on radon exchange dynamics between bedrock, cave waters (main collector and percolations) and indoor underground atmosphere. Radon air concentrations, normally high, increase more and more during collector's floods. An explanation of this fact is a radon-water solubilisation process more effective in flood events, because of a greater extension of the rock-water contact surface. Radon is then carried from the water into the cave and released to the air. To verify this, continuous measurements of radon concentration are needed not only in the air, but also in the waters of the cave. So we tested a new device for continuous radon monitoring in water, in connection with AlphaGuard radon monitor. Referring to the first six months of the current year 2010, we present and discuss, for different sections of the cave, the correlations between radon in the air, radon in the waters, and collector's stream flow fluctuations.

Radon in Soil Gas Concentration and Gamaspectrometry *in situ* - dependencies

Lenka Thinova[1], Ales Fronka[1], Katerina Rovenska[1,2]

[1] *Department of Dosimetry and Application of Ionizing Radiation, Faculty of Nuclear Sciences and Physical Engineering Czech Technical University of Prague, Brehova 7, Prague 1, 11000, Czech Republic*

[2] *Radon Expert Group, National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic*

thinova@fjfi.cvut.cz

The radon concentration in soil gas measurement may have a lot of difficulties in case of the very low permeable background or the water-bearing horizon which occurs in the sampling depth. The effort of some physicists to replace radon in soil gas measurement by in situ gamma spectrometry measurement has no significant physical background. Some measurements - combination of (standard and depth profiled) radon in soil gas measurement followed up by the soil permeability measurement and gamma spectrometry in situ (NaI(Tl) detector) on the earth surface and in shallow hole (with step 10 cm and synchronous soil sampling for laboratory gamma spectrometry measurement using the special sampling probe) in the regular net of sampling points were carried out. The radon concentration was correlated with contribution of ^{226}Ra and ^{214}Bi to the gamma spectra in the each point of measurement.

Set-up of a Radon Monitoring Station in a 100 m Height Tower in the Southern Coast of Spain

Claudia Grossi[1], Arturo Vargas[1], Delia Arnold[1], Israel Lopez-Coto[2], Juan Pedro Bolivar[2], Jose Antonio Adame[3], Benito Arturo De la Morena[3]

[1] *Institute of Energy Technologies, Politechnical University of Catalonia (UPC), Avinguda Diagonal 647, Barcelona, 08018, Spain*
[2] *Physics Department, Huelva University, Huelva, Spain*
[3] *National Institute for aerospace technology, INTA, Spain*

claudia.grossi@upc.edu

A station has been set up to measure radon and thoron concentrations at 10 m and 100 m height at the INTA-El Arenosillo, located in the South coast of Spain. This allows studying the influence of the thermal internal boundary layer and of the land-see breezes on radon and thoron concentrations.

The devices were self-designed aiming high sensitivity and low maintenance. The monitors are based on alpha spectrometry of ^{218}Po and ^{216}Po, which are collected electrostatically on a passive implanted detector. The monitor sensitive volume is a 15x10^3 cm^3 sphere, internally covered with silver. The detector is located on the sphere top and is electrically isolated. A potential of 8 kV is applied between the detector and the sphere walls to move the positive ^{218}Po and ^{216}Po ions on the detector surface. The calibration factor obtained in the INTE radon chamber is 0.38 cpm for radon and 0.12 cpm for thoron, per Bq m^{-3}.

Radon and thoron concentrations are hourly measured since October 2009. The station and monitors characteristics will be presented with set-up and preliminary results.

National programs and projects

oral presentaions

Necessity and Evolution of National Radon Programs

Francesco Bochicchio

Dept. on Technology and Health, Section "Radioactivity and Related Health Effects", Istituto Superiore di Sanita' (Italian National Institute of Health), Viale Regina Elena, 299, Roma, 00161, Italy

francesco.bochicchio@iss.it

The protection of population and workers from the health risk due to radon exposure requires many different actions and involves many different institutions, at national, regional and local level.

Therefore, a national program is a very useful tool to coordinate and optimize the required actions, especially in countries with a federal organization, as it is the case of Italy as regards the health organization.

Moreover, recent findings on radon risk evaluation and management promoted significant revision in international and national recommendations and regulations on radon, e.g. WHO recommendations and the International and the European Basic Safety Standards.

In this paper, the Italian National Radon Program will be shortly described, highlighting the main points related to current evolution and comparing with other countries, e.g. UK.

A review of characteristics of national radon programs as required by the current drafts of the International and European BSS will also be reported.

An Overview of the Activities of the RADPAR (Radon Prevention and Remediation) Project

J. Bartzis[1], H. Zeeb[2], F. Bochicchio[3], S. Kephalopoulos[4], James Mc Laughlin[1,5], B. Collignan[6], A. Gray[7], K. Kalimeri[1]

[1] *Department of Mechanical Engineering, University of Western Macedonia, Sialvera and Bakola Str., Kozani, 50100, Greece*
[2] *University of Bremen, Germany*
[3] *Instituto Superiore di Sanità, Italy*
[4] *EC Joint Research Center, Italy*
[5] *University College Dublin, Republic of Ireland*
[6] *Centre Scientific et Technique du Bâtiment, France*
[7] *University of Oxford, United Kingdom*

james.mclaughlin@ucd.ie

The RADPAR project (2009-2012) is part of the Second Programme of the European Community Action in the Field of Health and within the aegis of the Executive Agency for Health and Consumers (EAHC), of Directorate General SANCO. It commenced in May 2009 and is coordinated by the University of West Macedonia, Kozani, Greece. Its partners are from health, radiation protection and related institutions, in 15 European countries as well as the World Health Organisation. Its main objectives are the following:

- Improvement of strategies to reduce the EU public health burden from radon.
- Development of radon risk communication strategies and the creation of an EU radon information web site (*http://web.jrc.ec.europa.eu/radpar*).
- Assessment of cost-effectivness of radon control strategies in the EU.
- Design of training courses in radon measurement, prevention, remediation and cost-effectiveness.
- Assessment of potential conflicts between energy conservation in buildings and radon exposure reduction.

An account is given of the progress to date towards achieving these objectives.

Risk Awareness Studies - The First Step for a National Radon Strategy

Dieter Schlesinger[1], James Mc Laughlin[2,3]

[1] *Radiation Risk - Radiation Protection Concepts - Risk Communication, Federal Office for Radiation Protection, Ingolstädter Landstraße 1, Neuherberg, 85764, Germany*
[2] *University College Dublin, Stillorgan Road, Dublin, 4, Ireland*
[3] *University of West Macedonia, Kozani, Greece*

dschlesinger@bfs.de

Firstly, the necessity of a national radon strategy as well as the theoretical background to develop Risk Awareness Surveys (RAS) is presented. The main aspects which will be pointed out are a) "Behavioural Modification" concepts, and b) a marketing structure that helps to identify the most important target groups as well as major partners to distribute the ideas.

Secondly, based on this theoretical background the main aspects of a RAS will be developed. The central aim of which is to provide information to decision makers to develop strategies to reduce the public health burden of disease from radon. Therefore from a general population point of view the knowledge on radon, general risk perception and assessment, perceived effectiveness of measures as well as relevant stakeholder groups that should be integrated in a radon strategy must be identified.

Thirdly, the main results from two already completed RAS in Munich/Germany and Kozani/Greece as well as the final RAS – which is provided for free use on the RADPAR Project website - will be presented and discussed.

Radon Programme and Health Marketing

Ivana Fojtikova

Radon Expert Group, National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic

ivana.fojtikova@suro.cz

Being aware of negative health effects of radon exposure, many countries aim for reduction of the radon exposure of their population. Czech Radon Programme was commenced more than 20 years ago. Since then experts have gathered a lot of knowledge, necessary legislation has been enacted, tens of thousands inhabitants have been offered free measurement and subsidy for the mitigation. Despite the effort the effectiveness of the Radon Programme seems to be poor. Newly built houses still exhibit elevated radon concentrations and the number of houses mitigated is very low.

Is there possible to enhance the effectivity of Radon Programme while keeping it on the voluntary basis? One possible way is to employ Health Marketing that draws together traditional marketing theories and science-based strategies to prevention. Potential of using marketing principles in communication and delivery of radon information will be discussed.

An Overview of Ireland's National Radon Policy

Stephanie Long

Radon Advice, Radiological Protection Institute of Ireland, 3 Clonskeagh Square, Clonskeagh Road, Dublin, Ireland

slong@rpii.ie

In Ireland radon is a significant public health issue and is linked to 150 to 200 lung cancer deaths each year. Irish National Radon Policy aims to reduce individual risk by identifying and remediating buildings with high radon concentrations and also to reduce collective dose through radon prevention as required by revised Building Regulations. Achievements to date are significant and include the completion of the National Radon Survey, the testing of every school in Ireland, the on-going testing of social housing, collaboration between the public health and radiation protection authorities and the inclusion of radon in inspections of workplaces. However, this work now needs to be drawn together centrally to comprehensively address the radon problem. The RPII and its Governing Department are currently working to constitute a group of key experts from relevant public authorities to drive the development of a Government led National Radon Control Strategy for Ireland.

Finnish Radon Situation Analysed Using National Measurement Database

Tuomas Valmari, Ilona Mäkeläinen, Heikki Reisbacka, Hannu Arvela

Research and Environmental Surveillance, Finnish Radiation and Nuclear Safety Authority - STUK, Laippatie 4 (P.O.Box 14), Helsinki, FI-00881, Finland

tuomas.valmari@stuk.fi

STUK maintains the national indoor radon measurement database in Finland. The analysis of the database material supplements information on radon situation collected by random sampling studies. The 92 000 dwellings in the database are not a representative sample of the Finnish housing stock. However, the bias is compensated by calculating radon parameters in 1-km^2 cells and weighting the cells by the number of dwellings in the cell. Both the database material and a recent random sampling survey show that radon concentrations in new Finnish houses have been decreasing since the 1990s. This positive trend is clearly stronger in radon-prone areas where preventive measures are nowadays commonly implemented in new construction. The changeover to mechanical supply and exhaust ventilation has also contributed to the decrease in the concentrations. On the other hand, there is no definite general trend towards more radon-resistant foundation types.

Norway's National Radon Strategy: Preliminary Results for a Standardised Radon Measurement Protocol in Schools

William Standring[1], Jonas Holme[2], Baard Olsen[1], Lisbeth Alnaes[2], Christina Hassfjell[1]

[1] *Norwegian Radiation Protection Authority, Grini naringspark 13, Oesteraas, Oslo, 1361, Norway*

[2] *SINTEF Byggforsk Oslo, Forskningsveien 3b, Blindern, Oslo, 0314, Norway*

william.standring@nrpa.no

The Norwegian Radiation Protection Authority regards the generation of recommended standard radon measurement protocols for different building categories as important towards its ongoing work to facilitate implementation of the Norwegian Governments Strategy for the Reduction of Radon Exposure in Norway, published 1 June 2009. Regulatory revisions are currently underway in Norway that will include legally binding limits for indoor radon concentrations in schools, kindergartens and rented accommodation. The NRPA has therefore initiated a pilot project together with SINTEF Byggforsk to study radon levels in five schools in Southern Norway. The measurement protocol tested incorporates extensive passive radon measurements as well as a continual hourly logging of radon concentration in order to assess the effect of the different ventilation regimes at each school. This paper presents the results from the indoor radon mapping and discusses them in relation to possible measurement protocols.

Multivariate Statistics Analysis Applied to Indoor Radon Data in Portugal

Heloísa Fonseca, Mário Reis

Unidade de Protecção e Segurança Radiológica, Instituto Tecnológico e Nuclear, Estrada Nacional 10, Apartado 21, Sacavém, 2686-953, Portugal

mcapucho@itn.pt

The first Portuguese nation wide indoor radon survey started in 1987 and was carried out by the Radiological Protection and Nuclear Safety Department of the Nuclear and Technological Institute. This study was concluded in 1994 with the publication of the national survey, the first indoor radon map and an informative brochure. Nowadays, a new approach is being developed in order to obtain indoor radon risk probability maps through the use of geostatistic simulation techniques and data integration onto Geographical Information Systems (GIS). Radon gas can accumulate inside buildings as a result of several factors like geological and geographical factors, building materials, floor level, ventilation and human habits. Multivariate statistics analysis, such as principal component analysis, was used to investigate factors and processes that could influence the variation of indoor radon concentrations, helping to identify patterns and dependence in variables.

Handling Preferential Sampling in Areal Summary Statistics of Indoor Radon Concentrations

Angela Alberici[2], Riccardo Borgoni[1], Valeria Tritto[1], Daniela de Bartolo[2]

[1] *Dipartimento di Statistica, Universitè degli Studi di Milano Bicocca, Via Bicocca degli Arcimboldi 8, Milano, 20126, Italy*
[2] *Settore Aria e Agenti Fisici - U.O. Agenti Fisici ed Energia, ARPA Lombardia, Viale Restelli 3/1, Milano, 20124, Italy*

D.DEBARTOLO@arpalombardia.it

Many measurement campaigns of indoor radon concentration (IRC) have been undertaken in order to assess the exposure of people to Rn.

It is often required to estimate some characteristics of the spatial distribution of Y as the average or the probability of exceeding a fixed threshold.

The random function is sampled at n points $x_1, \ldots, x_n$ in D and sampling data are used to calculate some summary statistics.

If the random function is regular enough and sampling locations are regularly located within D, unweighted statistics can be used for estimating the aggregates of interest.

Usually IRC campaigns are not designed in this way. IRC monitoring networks are naturally clustered for a tendency of buildings to cluster in space and sampling is often intentionally preferential. Furthermore IRC shows trends or is locally not stationary. The consequence of this can range from inefficient estimates to seriously biased inferences.

In this paper we consider the problem induced by preferential designs of IRC on areal estimates and we compare some methods to adjust for this by using a large survey conducted in Lombardy (Italy) in 2003-4.

Indoor Radon Survey Procedure of Large Urban Settlement

Aleksandra Onishchenko, Ilya Yarmoshenko, Michael Zhukovsky

Radiation lab., Institute of Industrial Ecology UB RAS, S. Kovalevskoy, 20, Yekaterinburg, 620219, Russia

onischenko@ecko.uran.ru

The tasks of radon survey in Yekaterinburg city, Russia were to obtain an unbiased average level of indoor radon exposure, to determine the parameters of distribution, to estimate a dwelling quantity with elevated levels and to discover the main factors influencing radon entry. The main steps were as follow: generating a sample of 400 dwellings, selecting the measurement method – LR-115 track detectors, creating the questionnaire, estimating the seasonal radon variation. The annual average radon concentration 42 Bq/m^3 (geometric mean 30 Bq/m^3, σ_{LN}=0.84) was obtained. Considering the parameters of lognormal distribution predictable percentage of dwellings with radon level above 400 Bq/m^3 was 0.1%. Two groups of dwellings with higher average radon concentration were discriminated: apartments on the ground floor in buildings constructed in 1950-1969 and apartments in monolithic and brick multy-storey buildings, constructed after 1990. The average annual effective dose is 1.3 mSv.

Radon in Finnish Mines 1972-2009

Siiri-Maria Aallos-Ståhl, Eija Venelampi, Martti Annanmäki, Eero Oksanen, Mika Markkanen

STUK - Radiation and Nuclear Safety Authority, Laippatie 4, Helsinki, 00880, Finland

siiri-maria.aallos-stahl@stuk.fi

Radon measurements in Finnish underground mines were started in 1972. In 1975, a limit for radon concentration was set at 1100 Bq/m^3. In 1992, an action level of 400 Bq/m^3 for radon, an average over the total number of annual working hours, was adopted. Since then regular radon inspections have been carried out in all underground mines. In 1972 there were 23 operating underground mines in Finland. Today there are 11 underground mines in operation, most of them being small in size. In 2002 a survey was done to determine the average individual and collective doses of mine workers between 1975 and 2001 (M. Annanmäki et al). The purpose of this research is to continue the previous survey determining the doses for the mine workers in Finland from 2002 to 2009. Further aim for this research is to determine the average radon concentration in Finnish underground mines during the period.

Lung Cancer Risk From Occupational and Residential Radon – Comparison of Detriments

Ladislav Tomasek

National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic

ladislav.tomasek@suro.cz

The lung cancer risks from occupational and residential radon are compared using results of large Czech studies of uranium miners (11 000 miners, 1074 lung cancers) and 13 European studies of residential radon. Traditionally the risk in occupational studies is expressed per historical WLM units, whereas the risk in residential studies is related to unit radon concentration of 100 Bq/m^3 that was obtained during past 5-34 years. For comparison, the risk in miners is related to the same period 5-34 years and the exposures in both settings are expressed in terms of cumulated intake of radon progeny in MBq. As the risk in occupational studies is known to depend on exposure rate, the risk is adjusted to low annual levels of exposure. This conversion include important parameters, like breathing rates, equilibrium ratios, and duration of exposure. In addition, the results will result into conversion from Bq to Sv. The work was supported by the Czech Ministry of Health (IGA NS 10596).

Radon Program of the Czech Republic

Eva Pravdova, Karla Petrova

State Office for Nuclear Safety, Senovazne namesti, Prague, 110 00, Czech Republic

eva.pravdova@sujb.cz

The Radon Program of the Czech Republic 2010 – 2019. Action Plan is based on the Governmental Decision and coordinated by the State Office for Nuclear Safety.

The first Radon Program started in the Czech Republic in the early eighties. Its aim was to find buildings with a high radon concentration and to remediate them. It was found that the mean radon concentration in dwellings in our country is about 119 Bq/m^3. In spite of all the positive results and large amount of work done it was found that such a task can not be fulfilled in a limited period but that it is a long term effort.

That is why the new Radon Program Action Plan has been prepared for the period 2010 – 2019. It covers both prevention at new house construction and intervention in existing houses with high radon concentration.

National programs and projects

posters

Estimation of Radon Concentration and Annual Effective Dose in the Construction of Motorway

Chen Yue[1,2], Liu Qingcheng[1], Deng Juzhi[1], Yang Yaxin[1], Xu Guilai[2]

[1] *East China institute of Technology, Fuzhou, Jiangxi, 344000, China*
[2] *CNNC Beijing Research Institute of Uranium Geology, Beijing, 100029, China*

chenyue-11@163.com

Studies on estimation of radon concentration and annual effective dose in the construction of motorway, by ground-atmosphere exchange of radon which on the basis of the theory of diffusion and convection of radon.The parent of radon being uranium, uranium content is measured by γ spectrometer that are present radon in the environment. The results show tunnel line Radon concentration is 21.45-101.4 Bq/m^3 in air surpass four times of chinese natural radon concentration(24 Bq/m^3),it lead to the annual effective dose 0.2-0.96 mSv surpass limit value(0.5 mSv) by one times.Owning to the workplace abounds in uranium deposits. Radon radiation harm workers and surrounding masses in workplace.,each link should supervision and manage it.procedure of construction should pay attention to radon concentration,work men inhale and eat radiation in course of work,limit worktime.surrounding matter and water source should survey their radiant position to avoid pollution.

Indoor Radon Survey in Saudi Arabia

Mohammad Alamer

Physics Department, King Fahd University of Petroleum and Minerals, Dhahran Road, Dhahran, 31261, Saudi Arabia

mibrahim@kfupm.edu.sa

Indoor radon survey was carried out in a total of 2535 dwellings in four regions of Saudi Arabia, using NTDs based closed chamber radon dosemeters. The duration of the measurements was one year. The indoor radon concentrations varied from 1 to 535 Bq/m^3 with an overall average of 25 Bq/m^3 for all surveyed dwellings. The frequency distribution of the indoor radon concentrations for all the regions looks like log-normal Fifteen dwellings showed radon concentration above 200 Bq/m^3, Active measurements confirmed passive measurements. The Northern region showed the highest average indoor radon of 43 Bq/m^3 and the highest number of dwellings having high indoor radon. The average indoor radon in the other three regions varied between 17 and 20 Bq/m^3. Detailed investigations were carried out for three dwellings that showed high indoor radon using active and passive techniques. The low radon exhalation rates from the construction materials of the dwellings and the high soil exhalation rates suggest that the anomalous radon concentration is due to underground radon diffusion into the dwellings.

High-level Training about Radon in Swiss Universities of Applied Sciences

Joëlle Goyette-Pernot, R. Compagnon

CEN - Architecture, University of Applied Sciences of Western Switzerland, 80, Bd de Pérolles, Fribourg, 1705, Switzerland

joelle.goyette@hefr.ch

The Swiss Federal Office of Public Health FOPH has recently decided to hand over the training of future radon consultants to Universities of Applied Sciences in Switzerland. The goal is to rapidly introduce many of the issues regarding radon indoor pollution in the core of the formation in architecture and also to other stakeholders involved in this field.

To achieve this goal, the concept of radon consultantship was devised. Experts will thus by appointed by linguistic and cultural regions of Switzerland: German, French, and Italian. They will operate on the three main specific areas: strategy, training and field operation, the latter being the field analysis and the proposal of potential solutions.

Regarding the training, these three experts will collaborate on the development of similar programs in their regional Universities of Applied Sciences. A basic training is introduced during the bachelor degree. Trainings for postgraduates will then follow and one in particular will start in September 2011 aiming to train future experts and advisers in the field of indoor air quality. These experts will later benefit from follow-up days and subsequent exchanges of experiences.

The main interests and concerns of the FOPH are to develop a national and unique concept of consultantship to respond effectively to new standards that will soon become effective.

Methodology of Dose from Radon Calculation for Underground Workers in the Czech Republic

Lenka Thinova, Katerina Rovenska

Department of Dosimetry and Application of Ionizing Radiation, Faculty of Nuclear Sciences and Physical Engineering Czech Technical University of Prague, Brehova 7, Prague 1, 11000, Czech Republic

thinova@fjfi.cvut.cz

The project was focused on the classification of worker irradiation from natural ionizing radiation sources in publicly accessible caves and in caves used for speleotherapy, with an application to other underground workplaces. The correct and accurate procedure (and calculation) was defined for the determination of an effective dose obtained by workers in caves, based on the results of integral measurements of radon volume activity and on the duration of workers presence in the caves. Various approaches for evaluation of the lung irradiation found in literature were reviewed and experimental measurements of cave atmosphere characteristics (continuous measurement of radon volume activity, continuous and integral measurements of radon decay products, interior climatic parameters and aerosol spectra) were the main sources for the methodology.

Radon in the Environment and in Dwellings in a Uranium Mining Area in Eastern India: an overview

A. H. Khan, V. D. Puranik

Department of Atomic Energy, Bhabha Atomic Research Centre, Environmental Assessment Division, Trombay, Mumbai, 400085, India

ahkhan@barc.gov.in

Among many low grade uranium ore deposits in India mining is in progress in the Singhbhum Thrust Belt where radon has been extensively studied. Natural source of environmental radon is emanation from soil and technological sources include releases from mine exhausts, emanations from waste rocks and tailings surfaces. The emanation rates of radon from soil and rocks vary from 20 to 50 $mBq \cdot m^{-2} \cdot s^{-1}$ and that from waste rocks and tailings surfaces average at 300 and 1500 $mBq \cdot m^{-2} \cdot s^{-1}$, respectively. Atmospheric Rn levels near tailings ponds are 20 to 30 $Bq \cdot m^{-3}$ and the regional background radon in air averages at 15 $Bq \cdot m^{-3}$. Radon concentrations in dwellings vary from 25 to 159 $Bq \cdot m^{-3}$, with average at 100 $Bq \cdot m^{-3}$. Among the ground waters, the bore well waters show values around 100 $kBq \cdot m^{-3}$ but open wells show lower levels. Diurnal and seasonal variations are observed in outdoor and indoor radon. Variations are observed in ground waters too. A review of radon studies in STB is given.

Radon Indoors and Outdoors in Poland

Kalina Mamont-Ciesla, Katarzyna Woloszczuk, Anna Sosinska, Szczesny Rosinski, Olga Stawarz, Paweł Lipiński

Laboratory for Calibration of Dosimetric and Radon Instruments, Central Laboratory for Radiological Protection, Konwaliowa 7, Warsaw, 03-194, Poland

woloszczuk@clor.waw.pl

Since 1991 up to now a nationwide survey of Polish dwellings has been conducted to determine the radon exposure of the Polish population and prepare radon map for dwellings and outdoors. In the project several radon laboratories participated. Majority of the results come from: Central Laboratory for Radiological Protection, Warsaw and Institute of Nuclear Physics PAN, Krakow and were achieved by means of the passive solid state nuclear track detector (SSNTD) technique based on CR-39 foils in diffusion cups exposed from 6 to 12 months. In the maps there were also introduced results of the Medical University in Bialystok obtain with charcoal detectors. The total number of 3305 results of radon concentration in dwellings were used to produce the maps. For the data base the arithmetic mean is 85 Bq/m^3, geometric mean - 43 Bq/m^3 and mediana - 40 Bq/m^3. The highest value of radon concentration is 3 229 Bq/m^3.

On the basis of results from 5 macroregions of Poland: Bialystok, Gdynia, Katowice, Warszawa and Wroclaw (2081 dwellings) the dependence of the radon level on the type of building materials (red brick, hollow brick, wood, prefabricate), presence or absence a cellar under buildings and number of floor has been investigated.

In the paper the CLOR radon chamber to calibrate all kinds of detectors and devices for both: radon and radon progeny measurements is presented. The laboratory was accredited by Polish Accreditation Centre under number AP 101 (at present AP 057).

^{222}Radon Measurements in Tunisia - a Ten Years Experience

Michele El May, Latifa Ben Omrane, Azza Hammou

C.N.R.P. (Centre National de RadioProtection), Place Bab Saadoun, Tunis, 1007, Tunisia

elmay_michele@yahoo.fr

To determine natural radioactivity level and identify high radon concentration areas, indoor air radon concentrations are measured in Tunisia since 1999 using Kodalpha open alpha-track devices during two or three months. Determination of radon concentration in commercial water bottles began two years ago using the Alphaguard-Aquakit system. National median for domestic radon concentrations was 36 Bq m^{-3} in 1151 homes located in all the inhabited areas of Tunisia. Two areas where concentrations may be higher than elsewhere were surveyed during one year. The first one was an area of underground houses no longer inhabited. There, annual median air radon concentrations were 46.5 Bq m^{-3} in modern houses and 305 Bq m^{-3} in underground houses with a maximum of 1,563 Bq m^{-3}. The second area concerned a town where a phosphogypsum stocking site was cleaned up and domestic air radon controlled during works: annual median was 29 Bq m^{-3}. In nine different commercial water trademarks radon concentration was less than 20 BqL^{-1}. This ten years experience in Tunisia shows that till now radon concentrations in air houses and in commercial bottled waters are under the International Recommended levels.

Radon nature trail

Martin Jiranek[1], Katerina Rovenska[2]

[1] *Department of Building Structures, Czech Technical University, Faculty of Civil Engineering, Thákurova 7, Prague, 16629, Czech Republic*
[2] *Radon Expert Group, National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic*

katerina.rovenska@suro.cz

The aim of the trail is to inform people about radon – its risk, sources, mitigation and remediation possibilities – in a popular and understandable way. As location for the first radon trail, the city of Jachymov was selected. This city is historically connected with uranium and radium. Marie Curie Sklodowska discovered radium in pitchblende mined in Jachymov. Radon nature trail has 9 posted information boards which cover main parts of radon problem – Radon and health effects, Origin of Radon and its sources, Measurement of Radon, Radon and civil engineering with focus on the Jachymov city and Radon and legislation in the Czech Republic.

Radon in civil engineering

oral presentaions

Radon Preventive Measures with Special Emphasys on Radon-proof Membranes

Martin Jiranek, Monika Kotrbata

Department of Building Structures, Czech Technical University, Faculty of Civil Engineering, Thákurova 7, Prague, 16629, Czech Republic

jiranek@fsv.cvut.cz

Principles of designing and realization of radon preventive measures in the Czech Republic are described. Detailed information about the most frequently used measures such as the radon proof membrane, the sub-slab soil ventilation and the floor air gap ventilation is presented. Attention is focussed on applicability of various waterproofing materials as radon barriers. Barrier properties of membranes were verified in dependence on their chemical composition by measurement of the radon diffusion coefficient. Results of more than 350 insulating materials are summarized. We have found out that great differences exist in diffusion properties because the diffusion coefficients vary within eight orders from 10^{-15} m^2/s to 10^{-8} m^2/s. Performed tests confirmed that the radon diffusion coefficient is also a suitable parameter for expressing of air-tightness of joints. It can be concluded that this coefficient is a convenient parameter for selection and design of radon-proof membranes.

Residential Radon Remediation: A Seventeen Year Test of Durability

Naomi Harley, Passaporn Chittaporn, Anthony Marsicano

Environmental Medicine, New York University School of Medicine (Use Home Address), 1 Marine View Plaza, Apt 24E, Hoboken, New Jersey, 07030, United States

naomi.harley@nyumc.org

Radon measurements in the basement of a newly built home a New Jersey indentified relatively high concentrations. The owner installed a sub slab ventilation remediation system in the basement, i.e., PVC duct through the basement floor connected to a standard blower fan with exit air venting to a basement window. Measurements using the NYU alpha track detector began in 1992. The original version of the detector had triplicate chambers for radon measurement to permit a calculation of the precision of the measurement. The sub slab system reduced the baseline concentrations of 370, 55, 66 Bq m^{-3} for the basement, first and second floors respectively, to an average of 21, 13, 12 Bq m^{-3} over the seventeen year interval. The latest measurement in the basement, over a one year interval in 2008, used a later design NYU detector that included duplicate alpha track chambers for both ^{222}Rn (radon) and ^{220}Rn (thoron). The thoron and radon concentrations were 2 versus 20 Bq m^{-3} respectively.

Long-term Measurements of Thoron, its Airborne Progeny and Radon in 205 Dwellings in Ireland

James Mc Laughlin[1], Michael Murray[2], Lorraine Currivan[2], David Pollard[2], Veronica Smith[2], Shinji Tokonami[3], Atsuyuki Sorimachi[3], Miroslaw Janik[3]

[1] *School of Physics, University College Dublin, Stillorgan Road, Dublin, 4, Ireland*

[2] *Radiological Protection Institute of Ireland*

[3] *National Institute of Radiological Sciences, Chiba, Japan*

james.mclaughlin@ucd.ie

Long term simultaneous measurements of indoor concentrations of thoron gas and airborne thoron progeny were made using passive alpha track detectors in 205 dwellings in Ireland during the period 2007-2009. Thoron progeny concentrations were measured using passive deposition monitors designed at the National Institute of Radiological Sciences (NIRS), Japan while thoron gas concentrations were measured using Raduet detectors (Radosys, Budapest). Radon concentrations were also measured at the same time in these dwellings using standard alpha track radon detectors employed by the Radiological Protection Institute of Ireland (RPII).

The concentration of thoron gas ranged from < 1 to 174 Bq/m^3 with an arithmetic mean of 22 Bq/m^3. The concentration of radon gas ranged from 4 to 767 Bq/m^3 with an arithmetic mean of 75 Bq/m^3 . For radon the estimated annual doses were 0.1 (min), 19.2 (max) and 1.9 (arith.mean) mSv/year. The concentration of thoron progeny ranged from < 0.05 to 3.8 Bq/m^3 (EETC) with an arithmetic mean of 0.47 Bq/m^3 (EETC). The corresponding estimated annual doses were 2.9 (max) and 0.35 (mean) mSv/year.

Radon Emanation Coefficient for Brazilian Phosphogypsum

Nivaldo Carlos da Silva, Pâmela Braga da Silva Rosa

Laboratory of Poços de caldas - LAPOC, Brazilian Commission for Nuclear Energy, Rodovia Poços de Caldas - Andradas km 13, Poços de Caldas - MG, 37701970, Brazil

ncsilva@cnen.gov.br

Phosphogypsum - PG is a by-product from fertilizer industry, produced worldwide in large scale. The annual Brazilian production is estimated to be around $4.5{\cdot}10^6$ MTons while additional $70{\cdot}10^6$ MTons of this material are stockpiled nearby the fertilizer factories. Although its major component is calcium sulphate, PG may also have some impurities including naturally occurring radionuclides (mainly Ra-226). There is a great interest in using this material as a substitute for natural gypsum. In order to achieve this goal, potential radiological impact related to Rn-222 and its decay products should be properly controlled and overcome. Therefore, Rn-222 generation and transport processes are to be accounted for as far as the use of PG as an alternative building material is concerned. In short, this paper will present and discuss the whole methodology employed to assess such coefficient for phosphogypsum derived from two Brazilian industries.

Comparison of Two American Approaches to Indoor Radon Problems: Status and Challenges

William Angell

Midwest Universities Radon Consortium, University of Minnesota, 1985 Buford Avenue, St. Paul, MN, United States

wangell@umn.edu

Radon programs in Canada and the United States offer similarities and differences that are insightful for understanding trade-offs in national radon risk reduction strategies. This abstract compares the two national approaches to radon and identifies the successes and challenges. Health Canada's radon measurement protocol calls for long-term radon measurements similar to European recommendations while the U.S. Environmental Protection Agency's protocols allow for short-term measurements. Both countries focus on active soil depressurization approaches to radon remediation in existing residential structures with variations in recommended details of the systems. Radon control strategies in new homes feature similar details although the approaches are influenced by differences in building code procedures. The technical infrastructure varies between the countries. The more mature U.S. program has been criticized in recent years for failure to make overall progress in risk reduction.

Experimental Study for the Influence of Ambient Parameters on Indoor Radon Concentration

Romolo Remetti

Dpt. Basic and Applied Sciences for Engineering, "Sapienza"- University of Rome, Via Antonio Scarpa, 14, Roma, 00161, Italy

romolo.remetti@uniroma1.it

The study presents the results of a series of measurements, carried out by means of a Genitron AlphaGuard, of the variation of radon concentration in the 24 hours interval of the day. All the measurements have been intended to highlight the radon concentration variability during the 24 hours of the day and trying to set correlations with other ambient parameters such as temperature and pressure or local conditions such as the presence or not of forced ventilation system. The main part of the measurements have been carried in the area of the Nuclear Measurement Laboratory of the Engineering Faculty which, by chance, is situated over Roman catacombs of two thousands years ago: it seems that also the presence of catacombs, or in general, underground galleries, may play a certain role in radon concentration.

Assessment of ^{210}Pb Surface Contamination by Indoor Radon

Dusan Mrda, Istvan Bikit, Sofija Forkapic

Department of Physics, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovica 4, Novi Sad, 21000, Serbia

mrdjad@df.uns.ac.rs

Application of the model enables the estimation of indoor ^{222}Rn concentrations based on surface contamination by radionuclide ^{210}Pb in the closed or poorly ventilated room over a long period of time. The model is based on the fact that the change of indoor radon concentration, which periodically enters the room, affects only on radioactive decay and the inserted amount of radon in each impact, but not on its diffusion out, i.e. escape from the room.

Granulation Effects on Radon Emanation Rate

Istvan Bikit[1], Dusan Mrda[1], Selena Grujic[2], Uranija Kozmidis-Luburic[2]

[1] *Department of Physics, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovica 4, Novi Sad, 21000, Serbia*
[2] *Faculty of Technical Sciences, Trg Dositeja Obradovica 6, Novi Sad, 21000, Serbia*

bikit@df.uns.ac.rs

For several building materials, with different Ra-226 concentrations (ceramic plates, sand, brick, siporex brick), the effects of granulation on radon emanation rate are investigated. Ball mill is used in order to achieve different granulations of materials. The particle size distributions are determined by particle size analyzer (Master Sizer 2000). The increase of Rn-222 concentration inside closed chamber (volume $\approx 7 \times 10^{-3}$ m^3) due to emanation from each material with different granulation is measured by alpha spectrometer RAD7. Thus the time dependent curves of radon concentrations are obtained. Using gamma-spectroscopy method, the Ra-226 contents in all materials are determined. The strongest influence of granulation on radon emanation rate is found in the case of siporex brick sample.

Radon in civil engineering

posters

Detect and Evaluate the Concentration of Radon in Guangdong Residential Indoor Environment

Wu Zi-xiang, Yang Yu-hua, Liu Yan-bing

Guangdong prevention & Treatment Center for Occupational Diseases, 68 haikang St, Xinggang Rd,W.,Haizhu district, Guangzhou, 510300, China

wzx08118@163.com

Objective: To study the concentration of radon in Guangdong residential indoor environment and its relative effect factors.

Methods: Using a passive activated carbon indoor radon detector for detecting.

Results: In this study, the total arithmetic average concentrations of indoor radon were 46.1Bq/m^3 (in bedchamber) and 38.8Bq/m^3 (in living room). Detected on different building materials indoor, the average concentrations of radon were (53.5±19.2)Bq/m^3 in granite, (45.4±32.0) Bq/m^3 in tile and (29.7±21.20)Bq/m^3 in wood floor. The concentration of radon in winter was one-fold more than that in summer.

Conclusion: The total arithmetic average concentration of indoor radon in Guangdong was close to that of the world average (40.0 Bq/m^3). Concentration of indoor radon in Zhongshan and Boluo was one-fold higher than that of the world average.

Levels of Radon Activity Concentration in Air of Coal Mines in Bosna and Hercegovina

Z. Trešnjo[1], F. Adrovic[2], A. Trumic[3]

[1] *University Dzemal Bijedic of Mostar, Mostar, Bosnia and Herzegovina*
[2] *Department of Physics, Faculty of Natural Sciences and Mathematics, University of Tuzla, Univerzitetska 4, Tuzla, 75000, Bosnia and Herzegovina*
[3] *The International School of The Hague, Den Haag, Nederlands*

adrovicferiz@yahoo.com

By coal mining and exploatation, radioactive radon gas, which is captured in natural geological structures, is reallocated from the deep coal layers. Hence it is concentrated in the depots and coal seams of the mines or being transported to the surface of the earth where it can significantly change the levels of radioactivity in the working premises and residences. This paper presents the results of a three-year research of radon activity concentration in the air in hole and surface coal mines of Bosnia and Herzegovina. Detected concentrations of radon in the coal gaseous structure, atmosphere and other ambient media are in correlation with the properties of geological structures, technology of obtaining coal and meteo-climatic changes. It was measured with Alpha GUARD PQ 2000 radon portable measuring system (instruments Genitron-Frankfurt) and RadoMeter 2000 (Radosys LTD. Budapest), using the SS-NTD method.

Radon Exhalation from Phosphogypsum Bricks

Lucas José Pereira da Costa, Marcia Pires de Campos, Marcelo Bessa Nisti, Barbara Paci Mazzilli

Laboratório de Radiometria Ambiental, Brazil / IPEN-CNEN/SP, Av. Prof. Lineu Prestes, 2242, São Paulo, 05508000, Brazil

mpcampos@ipen.br

Phosphogypsum can be classified as TENORM and one of the main environmental concerns of its use is the radon exhalation from this material.

The recycling of the phosphogypsum is very important from the social-economic point of view and also regarding environmental preservation. A possible way to reuse of phosphogypsum is the manufacture of building materials.

The aim of this study is to evaluate the radon exhalation from phosphogypsum bricks used at houses construction.

A practical approach to measure radon exhalation rates directly from the surface of the material is to allow radon to build up in a container over time. The device used to this practical radon measuring are called accumulator.

In this study a hermetically closed glass can had been used as the accumulator. The phosphogypsum brick and a diffusion chamber with CR-39 were enclosed inside the accumulator. The exhalation rate was determined through the radon concentration at accumulator.

It were assessed the radon exhalation rate from bricks manufactured with phosphogypsum from different origins.

A Study on Production of Radon-proof Substances for Building Materials

Seonhohg Ki[1], Dohyeon Kim[1], Jongpill Park[1], Jihoon Kim[1], Malgobalgaebitnala Yoo[1], Rashid Khaydarov[2], Seungyeon Cho[1]

[1] *Department of Environmental Engineering, Yonsei University, 316 Baekwoon, Wonju, Gangwondo, 220-710, Republic of Korea*

[2] *Institute of Nuclear Physics, Uzbekistan Academy of Sciences, C-1, Bld.1, Apt. 111, Tashkent, Uzbekistan*

seon84@gmail.com

The purpose of this study was to create radon-proof chemicals to prevent the infiltration of radon gas into building materials, such as concrete in basements, slabs and walls. In addition, further removals not only for radon gas, but also for water, water vapour, volatile organic compounds (VOCs), as well as organic and inorganic gases were studied. The radon-proof chemicals consist of a blend of silicate organic compounds and agents for penetrating the chemicals into concrete. Silanes and siloxanes can penetrate into concrete and form a waterproof layer. However, they cannot seal pores to prevent gases and vapours from infiltrating into concrete. Therefore, different chemicals need to be added to the silanes and siloxanes. Activities focused on in this study can be divided into 2 categories: (a) the creation of the chemicals; and (b) the improvement of chemicals on the base of experiments with concrete to reach the best diffusion coefficient of chemicals, durability of concrete, and sealing properties.

Health effects of radon

oral presentaions

Radon Lung Dosimetry Models

Werner Hofmann, Renate Winkler-Heil

Division of Physics and Biophysics, Department of Materials Research and Physics, University of Salzburg, Hellbrunner Str. 34, Salzburg, 5020, Austria

Werner.Hofmann@sbg.ac.at

Two different modelling approaches are currently used to calculate doses to the lungs following the inhalation of short-lived radon progeny: (i) the semi-empirical ICRP compartment model and airway generation models. The stochastic generation model IDEAL-DOSE simulates the lung morphometry, the transport, deposition, clearance of inhaled particles, and the cellular dosimetry by Monte Carlo methods.

Specific topics addressed in this presentation are, among others, (1) Distributions of doses among bronchial airway generations; (2) Comparison of bronchial doses between non-smokers and smokers; (3) Anatomical and biological sources of intra-and intersubject variabilities of bronchial doses; (4) Which are the sensitive target cells? (5) inhomogeneity of the activity and resulting doses within bronchial airway bifurcations; (6) from energy distributions in sensitive bronchial cells to average lung doses which can be related to epidemiological data.

Prediction of Lung Cancer Risk for Radon Exposures Based on Cellular Alpha Particle Hits

Lucia Adina Truta Popa[1], Constantin Cosma[1], Werner Hofmann[2]

[1] *Faculty of Environmental Science, University Babes-Bolyai, Kogalniceanu, Cluj-Napoca, 3400, Romania*

[2] *Department of Materials Research and Physics, University of Salzburg, Salzburg, Austria*

popaluciadina@hotmail.com

To explore the role of the multiplicity of cellular hits by radon progeny alpha particles for lung cancer incidence, the number of single and multiple alpha particle hits were computed for basal and secretory cells in the bronchial epithelium of human airway bifurcations. Hot spots of alpha particle hits were observed at the branching points of bronchial airway bifurcations. The effect of single and multiple alpha particle intersections of bronchial cells during a given exposure period, selected from a Poisson distribution, on lung cancer risk were simulated by a transformation frequency – tissue response model, based on experimentally observed cellular transformation and survival functions. Calculations of lung cancer risk at low radon exposure levels suggest that single hits produce a linear-dose response relationship, while the superposition of single and increasing multiple hits at higher exposure levels may also be approximated by a quasi-linear dose-effect curve. The simulations predict a carcinogenic enhancement effect for radon progeny accumulations at bifurcation branching sites, which may increase current risk estimates.

MonteCarlo Calculation of the Energy Deposit in Tissue from Radon's Daughters in Epithelial Cells Layers in Human Lung

Arturo Angeles

Radiation Protection, Instituto Nacional de Investigaciones Nucleares, Km 36.5 Carretera Mexico-Toluca, La Marquesa, Ocoyoacac, 52750, Estado de Mexico

arturo.angeles@inin.gob.mx

The analysis of energy deposited in epithelial cell layers in human lung from radon´s daughters is presented in this work. Deposit energy values were obtained using a MonteCarlo method.

Absorbed fractions and dose conversion coefficients values have been presented for some authors in past considering different tissue models, basically from ICRP 66 and NRC, and some models variants.

Point sources deposition from Po-218 and Po-214 and different thickness for secretory and basal epithelial cell layers in bronchial and bronchiolar regions from 1 to 15^{th} lung generations have been considered. Absorbed values have been compared with the others one from ICRP 66.

Calculated absorbed fractions modified the conventional absorbed a dose; this approach is a better approximation for the dose values in lung tissues.

Lung Dosimetry for Inhaled Long-Lived Radionuclides and Radon Progeny

Majid Hussain[1,2], Renate Winkler-Heil[1], Werner Hofmann[1]

[1] *Division of Physics and Biophysics, University of Salzburg, Hellbrunnerstrasse 34, Salzburg, 5020, Austria*

[2] *Directorate General of Safety, 44000, Islamabad, Pakistan*

majid.hussain@sbg.ac.at

Up to now, the stochastic lung dosimetry model IDEAL-DOSE considers deposition in the whole of the lung, while clearance was restricted to bronchial airways. However, for the inhaled long-lived radionuclides (LLR), alveolar clearance has also to be considered for the calculations of alveolar as well as the bronchial doses. Thus the primary objectives of this study were (i) to develop stochastic clearance model in the alveolar region, (ii) to calculate total lung dose contribution from LLR in addition to radon progeny. Dose calculations were performed on the basis of average transport rates proposed for the revision of the ICRP Human Respiratory Tract Model. The results obtained indicate that LLR cleared from the alveolar region can deliver up to 2-6 times higher doses in the bronchial region as compared to the LLR directly deposited there. Comparison of LLR doses to that of short-live radon progeny predicts that LLR in uranium mines can deliver up to 5 percent of the doses allowed from the short lived radon progeny.

A Survey of Current Radon Pollution in Typical Uranium Mines in China

Guoxiu Qin, Qingcheng Liu

Institute of Nuclear Engineering and Technology, East China Institute of Technology, XueFu road, FuZhou, 344000, China

qinguoxiu198201@163.com

From May 2005 to May 2009, a survey of the air radon and its progeny in the workplaces (exclude underground) and residential areas in two typical uranium mines in China had been done by balloon method. The survey highlights that, the annual mean concentrations of radon in the workplaces of the two uranium mines were 223Bq·m^{-3} and 147Bq·m^{-3} respectively, the mean concentrations of outdoor radon in the residential areas were 27.4Bq·m^{-3} and 23.3Bq·m^{-3}, with the mean concentrations of indoor radon were 37.2Bq·m^{-3} and 32.9Bq·m^{-3}. The annual effective dose by exposure to radon and its progeny received by people working and living in number 1 uranium mine were concluded to be 1mSv and 1.47mSv respectively; and the annual effective dose of people working and living in number 2 uranium mine were 0.83mSv and 1.33mSv. The yield of uranium mine, storage of uranium waste, geological formation and meteorological condition etc. were the main factors influenced the concentration distribution of radon and its progeny in the workplaces and residential areas in the uranium mine.

Cancer Risk Assessment after Radon Inhalation: Results from European Research Program and Contribution to ICRP Statement on Radon Risk

Margot Tirmarche

Institute for Radiological Protection and Nuclear Safety, IRSN/DS, 31 Avenue de la Division Leclerc, B.P.17, Fontenay-aux-Roses Cedex, F-92262, France

margot.tirmarche@irsn.fr

This review is the result of a synthesis realized by the consortium* of the FP6 European project called Alpha-risk and is based on recent results obtained from the joint analysis of the Czech, French and German cohort studies of uranium miners. It considers the estimated excess relative risk of lung cancer per unit of exposure, by modelising the influence of chronic exposure over more then 10 years , (time since exposure, since median exposure, age attained or age at exposure...) The interaction of radon and tobacco consumption is also studied

In parallel to this European research program, international committees like WHO and ICRP were reconsidering their position in regard to radon risk assessment , based on recently published results of uranium miners and on a large number of case-control studies, studying lung cancer and domestic radon (exposure period : at least 25 years prior to the diagnosis of cancer). Joint international analyses concluded to very comparable results when considering the North American, European and Chinese data.

* *ALPHA RISK CONSORTIUM and recently published results on:* http://www.alpha-risk.org

Consequences and Correction of Measurement Errors Associated to Radon Exposure in the French Cohort of Uranium Miners

Allodji Setcheou Rodrigue[1,4], Leuraud Klervi[1], Henry Stephane[2], Benichou Jacques[3], Laurier Dominique[1,4]

[1] *IRSN/DRPH/LEPID, Institute for Radiological Protection and Nuclear Safety (IRSN), BP 17, Fontenay aux Roses, 92262, France*
[2] *Medical Council Areva Group, Paris, France*
[3] *Department of Biostatistics, INSERM, U657 / Department of Biostatistics, University of Rouen Medical School and Rouen University Hospital, France, Rouen, France*
[4] *University of Paris XI, Villejuif, France*

rodrigue.allodji@irsn.fr

Measurement errors (ME) are a serious problem in the analysis of epidemiological data. We carried out a simulation study to assess the effect of ME on the relationship between radon exposure and lung cancer death, based on the French cohort of uranium miners. Starting from a scenario without ME, we added ME considering different structures, i.e., Berkson vs. classical ME with possible succession of Berkson and classical ME to reflect changes in radon exposure measurement over time. We also evaluated the performance of ME correction methods, i.e., the regression calibration, the distribution correction and the simulation extrapolation. The simulation results show that ME lead to an attenuation to the null of the effect of the risk factor, with substantial bias on risk estimates. This bias is more noticeable for multiplicative Berkson ME than for multiplicative classical ME. All ME correction methods permitted to reduce largely the bias on risk estimates, but with different performance.

Interaction of Radon and Smoking Among Czech Uranium Miners

Ladislav Tomasek

National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic

ladislav.tomasek@suro.cz

The study is based on a case-control study nested within a cohort study (11 000 miners, 1074 lung cancers). The controls are individually matched by year of birth and attained age. Smoking data were collected in person or from relatives of deceased subjects or from medical files. The study resulted in 876 cases of lung cancer with smoking data. The linear dependence of lung cancer relative risk on radon exposure adjusted for smoking was not substantially different from analyses when smoking was ignored and reflected mainly the risk among smokers. However, the excess relative risk per unit exposure among never-smokers (74 cases) was substantially higher in comparison to that in smokers, reflecting differences in lung morphometry and clearence. The relative risks from combined effects are substantially lower than the risk derived from the multiplicative model, but somewhat higher than those from the additive model. The work was supported by the Czech Ministry of Health (IGA NS 10596).

Lung Cancer Risk and Absorbed Lung Doses due to Multiple Radiation Exposures among French Uranium Miners

Estelle Rage[1], Blandine Vacquier[1], Eric Blanchardon[1], Sylvaine Caër-Lorho[1], James Marsh[2], Alain Acker[3], Dominique Laurier[1]

[1] *Institute for Radiological Protection and Nuclear Safety, Fontenay-aux-Roses, France*
[2] *Health Protection Agency, Chilton, Didcot, United Kingdom*
[3] *AREVA NC - Coordination médicale, Paris, France*

estelle.rage@irsn.fr

This study aims to assess the risk of lung cancer death associated to the cumulative lung doses arising from the exposure to alpha (radon gas, radon short-lived progeny (RnP), long-lived radionuclides (LLR)) and non alpha (gamma rays) emitters among the French cohort of uranium miners. This study included 3271 exposed miners followed-up between 1956-1999. Lung doses were calculated with the ICRP Publication 66 Human Respiratory Tract Model. Mean alpha and non-alpha absorbed doses were equal to 78 and 56 mGy, respectively. RnP contributed for 97% to the alpha dose. A significant excess of relative risk (ERR per Gy [95%CI]) was associated to the total absorbed dose (3.0 [0.8-7.6]), to the alpha absorbed dose (4.6 [1.3-11.0]) and to the non alpha absorbed dose (7.5 [1.8-20.1]). Assuming a radiation weighting factor of 20 for alpha radiation, the ERR per Sv were 0.2 [0.1-0.5] and 0.2 [0.1-0.6] respectively for the total equivalent dose to lung and the alpha equivalent dose to lung.

Effect of Radon Measurement Methods on Dose Estimation

Norbert Kavasi[1], Tibor Kovacs[2], Eszter Deak[3], Katalin Nagy[3], Yosuke Kobayashi[1], Tetsuo Ishikawa[1], Shinji Tokonami[1]

[1] *Environmental Radiation Effects Research Group, 2. National Institute of Radiological Sciences, 4-9-1 Anagawa, Inage-ku, Chiba, 263-8555, Japan*
[2] *Institute of Radiochemistry and Radioecology, University of Pannonia, Egyetem u. 10, Veszprém, 8200, Hungary*
[3] *Department of Rheumatology, Markhot Ferenc; County Hospital, Fürdō u. 3-4, Eger, 3300, Hungary*

norbert@fml.nirs.go.jp

In the Turkhis bath of Eger (Hungary) radon concentration (CRn) was measured, using passive (P), active (A) and personal radon dosimeter (PRD) methods. Equilibrium factor (F) also was measured using active method. In addition external gamma dose rate (EG) measurement was achieved. In the old therapeutic building using P method the annual average radon concentration (ARn) and the estimated dose (E) were 800 $Bq \cdot m^{-3}$ and 5 $mSv \cdot year^{-1}$, respectively. In case of A and PRD method, the same values were 450 $Bq \cdot m^{-3}$, 2.9 $mSv \cdot year^{-1}$ and 200 $Bq \cdot m^{-3}$, 1.2 $mSv \cdot year^{-1}$, respectively. The measured average F was 0.2, which two times smaller than the recommended 0.4 value, therefore the E was decreased to 0.6 $mSv \cdot year^{-1}$. In the new therapeutic building the ARn was only 80 $Bq \cdot m^{-3}$, which means 0.5 $mSv \cdot year^{-1}$ or 0.2 $mSv \cdot year^{-1}$ depend on the recommended or the measured F used. In the old and new therapeutic building the EG were 0.3 $mSv \cdot year^{-1}$ and 0.1 $mSv \cdot year^{-1}$, respectively.

Influence of Real Living Ambient Conditions on Measurements Related to Dose

Karel Jilek, Josef Thomas, Ladislav Tomasek, Miriam Marusiakova

Radon expert group, National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic

karel.jilek@suro.cz

The unattached fraction of radon decay product clusters f_p and equilibrium factor F are dose relevant parameters in all dosimetric approaches to dose calculation. In the past four years, weekly continuous measurements of radon gas, unattached and attached activity concentrations of each radon progeny and air exchange rate were carried out in forty occupied typical Czech family houses. Based on measured values f_p and F, we focused on the assessment of changes in contribution of dose rate for members of public both under the influence of realistic living conditions differing in the total aerosol concentration, aerosol size distribution and air exchange rate and due to different approaches to its calculation i.e. via conservative equilibrium factor $F = 0.4$ instead of really measured. The results and outline of QA programme for used measurement instruments based on the NRPI Radon chamber facilities, including Scanning mobility aerosol particle sizer are reported.

A Review of Exposures to Radon, Long Lived Radionuclides, and External Gamma at the Czech Uranium Mine

Miriam Marusiakova[1], Zdenek Gregor[2], Ladislav Tomasek[1]

[1] *National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic*

[2] *GEAM, DIAMO, Dolni Rozinka, Czech Republic, Czech Republic*

miriam.marusiakova@suro.cz

The presentation is based on recent observations in the Rozna uranium mine in the Czech Republic. In this mine, which has been operated since the early 1960s, personal ALGADE dosimeters have been used since 1998. In the period 2000 – 2009, about one thousand workers have been monitored and there were about 400 miners on average working in the mine monthly.

We describe annual exposures to radon decay products, long lived alpha emitters and the external gamma radiation. These components play an essential role in estimation of the total effective dose. In addition to the distribution of these components, we study correlations among the three exposure components, including partial correlations where the effect of exposure duration is removed. We also assess the dependence of the exposures on the type of the mining job.

Implications of Polarity of Unipolar Ionisers on Reduction of Effective Dose Attributable to Thoron Progeny

Manish Joshi, Balvinder Sapra, A. H. Khan, Pallavi Kothalkar, Rajni Modi, Y. S. Mayya

Radiological Physics & Advisory Division, Bhabha Atomic Research Centre, Mumbai, 400085, India

mjoshi@barc.gov.in

Limited studies have been carried out to compare the effect of polarity of ions on the reduction of activity due to radon (^{222}Rn) or thoron (^{220}Rn) progeny using unipolar ionisers. Moreover, the implication of this reduction in activity to the inhalation dose is a crucial aspect to be examined. The present study comprises of investigating the effect of negative and positive ionisers (NIG & PIG) on thoron progeny activity. The activity concentration of ^{212}Pb was found to decrease from 45 Bq/m^3 to 6 Bq/m^3 in with a characteristic decay time of 14.7 ± 3.29 minutes and from 70 Bq/m^3 to 3 Bq/m^3 (5.57 ± 0.91 minutes) for the NIG & PIG respectively. The operation of the ioniser increased the unattached fraction by a factor of 10 and 4 with a decrease in attachment rate from 2.52 to 0.545 h^{-1} and 23 to 11.8 h^{-1} for PIG & NIG respectively. The dose reduction factor calculated on the basis of thoron decay product dose conversion factors was 1.9 for negative ioniser case compared to 4.9 for positive ioniser for the experimental conditions.

Health effects of radon

posters

Assessment of Effective Doses from Radon Levels at Some Brazilian Caves Galleries with CR-39 Detectors: Preliminary Results

Simone Alberigi, Brigitte Pecequilo, Marcia Campos

LRA (Environmental Radiometric Laboratory), IPEN (Institute of Nuclear and Energetic Researches), Av. Lineu Prestes, 2242, São Paulo, 05508000, Brazil

salberi@ipen.br

Radon and radon progeny are the greatest sources of natural radioactivity, being, by far, the most important contributors to the committed effective dose received by population.

Concentrations of indoor radon and its progeny in caves vary from levels hardly higher to levels several thousand times higher than outdoor air concentrations. Prolonged exposure to such high concentrations increases the risk of harmful effects to the health.

Radon Concentrations have been bimonthly and quarterly measured in the Santana Cave, the most frequented cave of PETAR (High Ribeira River Tourist State Park), situated at Sao Paulo State, Brazil. The measurements are carried out with CR-39 detectors. Preliminary results at Sao Paulo Saloon, for example, show a radon concentration of 8,4 $\pm$ 0,6 kBq·m^{-3}. The measurements started in November 2009 and the complete evaluation will be concluded on November 2010, with the estimation of effective dose received for the guides and the visitants.

Assessment of Lung Cancer Risk from Radon in Five Provinces of Iran

Samaneh Baradaran[1,2], Saeed Setayashi[2], Mehran Taheri[1]

[1] *National Radiation Protection Department,Iranian Nuclear Regulatory Authority, Tehran, Iran*

[2] *Medical Radiation Department, Amirkabir University of Technology, Terhan, Iran*

samabaradaran@yahoo.com

Radon is a natural radioactive gas which is produced by decaying the uranium and emanates from the ground. According to the Iranian report of cancer cases since 1985, lung cancer is the second most common death among all cancers (after stomach cancer).

Regarding to previous studies, the average radon levels were measured 80, 80, 88, 99, 137 Bq/m^3 for Tehran, Khorasan Razavi, Mazandaran, Hamadan, and Yazd respectively, therefore we estimated lung cancer risks for these provinces based on National Academy of Science report(NAS, USA), 1999, as $1.28{\cdot}10^{-2}$, $1.28{\cdot}10^{-2}$, $1.4{\cdot}10^{-2}$, $1.58{\cdot}10^{-2}$, $2.19{\cdot}10^{-2}$ respectively. EPA, UNSCEAR and ICRP risk factors were used for estimation of excess lifetime cancer risk which leads to 5-260 M PY^{-1}, 60-290 M PY^{-1} and 102-175 M PY^{-1} respectively.

Based on the report of the National Institute of Cancer and the Iranian Ministry of Health, the total death due to lung cancer were estimated to be, 5.7%, 4.82%, 4.48%, 3.76%, 9% in mentioned provinces. An investigation study was made on the relation between lung cancer risk and radon levels.

Analysis of Radon and Thoron Inside Different Phytotherapeutic Drug Preparations and Resulting Radiation Doses to Adult Patients

Mohamed Karime, M.A. Misdaq, Z. Essaouif

Nuclear Physics and Techniques Laboratory, Faculty of Sciences Semlalia, University Cadi Ayyad, My abdelah-semlalia, Marrakech, 40000, Morocco

karimemohamed@hotmail.com

Medicinal plants are presently used as tonic and for the treatment of different diseases by populations all over the world. Alpha-activities per unit volume due to radon and thoron were measured inside various classical and modern phytotherapeutic drug preparations widely used by the Moroccan populations. The influence of mass intake and pollution on the radon and thoron concentrations inside the studied therapeutic drug preparations was investigated. Annual committed effective doses due to radon and thoron from the ingestion of the studied therapeutic drug preparations by adult patients were evaluated.

Analysis of Radon and Thoron in Massage Oils Extracted from Aromatic and Medical Plants and Resulting Ratiation Doses to the Members of the Public in Spas and Fitness Clubs

K. Outeqablit, Mortassim Azeddine, M.A. Misdaq

Faculty of Sciences Semlalia, BP. 2390, University Cadi Ayyad, Marrakech, Morocco, Semlalia, Marrakech, 40000, Morocco

a.mortassim@ucam.ac.ma

Radon and thoron concentrations were measured in different plant oils and their corresponding aromatic and medicinal plants by using a technique based on evaluating the mean critical angles of etching of the CR-39 and LR-115 II solid state nuclear track detectors. The annual committed effective dose to the skin of adult members of the public from the application of the studied plant oils were evaluated. The influence of the period of application of the studied plant oils to the bathers on the resulting radiation doses was investigated.

Environmental Radon Exposure and Human Health Risk

Alina Louro[1], Sandra Soares[1,2], Luís Peralta[1,3], Alcides Pereira[4], Gilda Cunha[5], Ana Belchior[6], Octávia Gil[6], Pedro Teles[6], M. Joao Silva[7], H. Louro[7], Sebastiao Rodrigues[8]

[1] *LIP, Laboratório de Instrumentaçao e Física Experimental de Partículas, Av. Elias Garcia, 14, 1186;, Lisboa, 1000, Portugal*

[2] *UBI, Universidade da Beira Interior, Av. Marques d'Ávila e Bolama, Covilha, 6200, Portugal*

[3] *FCUL, Faculdade de Cincias da Universidade de Lisboa, Lisboa, Portugal*

[4] *IMAR, Dep. Earth Sciences, University of Coimbra, Coimbra, Portugal*

[5] *ESTEsL, Escola Superior de Tecnologias da Saúde, Lisboa, Portugal*

[6] *ITN, Instituto Tecnologico e Nuclear, Estrada Nacional, Sacavém – Lisboa, Portugal*

[7] *FCM, Department of Genetics, Faculty of Medical Sciences, Lisboa, Portugal*

[8] *INSRJ, Centro de Genética Humana, Inst. Nac. de Saúde Dr. Ricardo Jorge, Lisboa, Portugal*

shsoares@lip.pt

The principal hazard associated with radon gas is lung cancer induction, mainly due to its short-lived progeny. Their progeny is retained in the respiratory system, decaying one into the other, and deposited all their alpha-particle energy within the bounds of the respiratory system.

Epidemiological studies have provided convincing evidence of the association between indoor radon exposure and lung cancer, even at the relatively low radon levels commonly found in residential buildings [1].

The main purpose of this project is to assess the radon exposure distribution of the population in Guarda region. The study included 185 randomly chosen. For the dosimetric study, all the detectors were placed inside each dwelling. The preliminary results indicate that 66% of the dwellings present radon concentrations above 400 Bq/m^3, being 33% above 800 Bq/m^3. This may be an indication that the soil where the dwelling was build can be the dominant factor.

References

[1] WHO handbook on indoor radon-a public health perspective, WHO Press, Geneva, 2009, ISBN9789241547673, 2009.

Leukaemia Risk Among European Uranium Miners in Dependence on Doses from Radon, External Gamma, and Long Lived Radionuclides

Ladislav Tomasek[1], Estelle Rage[2], Dominique Laurier[2], Klervi Leuraud[2], Bernd Grosche[3], Michaela Kreuzer[3], Florian Dufey[3], James Marsh[4], Dietmar Nosske[3], Eric Blanchardon[2], Irena Malatova[1], Demetrio Gregoratto[4], Werner Hofmann[5]

[1] *National Radiation Protection Institute, Bartoskova 28, Prague, CZ 14000, Czech Republic*
[2] *Institute for Radiological Protection and Nuclear Safety, France*
[3] *Federal Office for Radiation Protection, Germany*
[4] *Health Protection Agency, Radiation Protection Division, United Kingdom*
[5] *University of Salzburg, Austria*

ladislav.tomasek@suro.cz

The study presents recent findings based on leukaemia mortality (69 cases) in three European cohort studies of uranium miners, including 9979 Czech, 3271 French, and 34 994 German miners. The risk is analyzed in relation to cumulated equivalent dose from radon and its progeny, external gamma radiation, and long lived alpha radionuclides. The doses to the red bone marrow have been calculated from annual exposure data for each miner from the first year of employment to the end of follow-up using the ICRP dosimetric and biokinetic models. The mean cumulated equivalent doses in the entire study are 38 mSv from external gamma, 42 mSv from radon and its progeny, and 18 mSv from long lived radionuclides. The estimated risk coefficient 3.7 per Sv (90%CI: 1.1 – 8.8) is consistent with estimates from the study of A-bomb survivors. The work was supported by the European Commission under FP6 (FI6R 516483) and by the State Office for Nuclear Safety of the Czech Republic (VZ 60022490).

Measurements of Natural Radiation Levels and Effective Dose Due to ^{222}Rn Concentration and Gamma Radiation in Alisadr Tourist Cave of Hamadan, Iran

Mehran Taheri[1], Mansour Jafarizadeh[1,2], Samaneh Baradaran[1], Mohammad Moradi[1], Naser Rastkhah[3,4], Mohammad Reza Kardan[1,3]

[1] *National Radiation Protection Department, Iranian Nuclear Regulatory Authority, Tehran, Iran*

[2] *Agriculture, Medicine and Industry Research School, Nuclear Science and Technology Research Institute, Karaj, Iran*

[3] *Radiation Application Research School, Nuclear Science & Technology Research Institute, Tehran, Iran*

[4] *Iranian Nuclear Regulatory Authority, Tehran, Iran*

mmtaheri@yahoo.com

The seasonal variations of radon concentration and environmental gamma dose were measured in Alisadr tourist cave based on the passive long-term measurement using polycarbonate detectors and TLD. The study has been carried out at selected 20 sites inside the cave along the tourist passage. Distinct seasonal variations were observed in the radon concentration so the maximum occurred in the spring, whereas the minimum occurred during the winter. Based on the measurements the average annual radon concentration was determined to be 1300 Bq·m^{-3} which is more than annual value recommended by ICRP for workplaces. The obtained results indicate an annual effective dose range of 4.8 to 11.2 mSv considering an equilibrium factor of 0.4 and a working time of 2000 hours/year. Graphical distribution of ^{222}Rn concentration are also presented and discussed.

Radon in Workplaces: First Results of an Extensive Survey and Comparison with Radon in Homes

Silvia Bucci[1], Gabriele Pratesi[1], Marta Pantani[1], Maria Letizia Viti[1], Francesco Bochicchio[2], Gennaro Venoso[2]

[1] *Florence Department, Italy/Florence/ARPAT, via Ponte alle Mosse 211, Florence, 50144, Italy*

[2] *Italy/Rome/ISS, viale regona Elena 299, Rome, 00161, Italy*

s.bucci@arpat.toscana.it

Extensive radon surveys have been carried out in many countries only in dwellings, whereas surveys in workplaces are rather sparse and generally restricted to specific workplaces/activities, e.g. schools, spas, caves.

Moreover, radon-prone areas are generally definided on the basis of radon surveys in dwellings, while radon regulations use this concept to introduce specific requirementes in workplaces in such areas.

This apporach does not take into account that work activities and workplace characteristics can significantly affect radon concentration.

Therefore, an extensive survey on radon in different workplaces have been carried out in a large Region of Italy (Tuscany), in order to evaluate radon distribution in workplaces over the whole territory and to identify activities and workpace characteristics affecting radon concentration. Moreover the results of this extensive survey are compared with the results of the survey carried out in dwellings in the same period.

The workplaces monitored where randomly selected among the main work activities in the region, including both public buildings and buildings used used for industrial and handicraft activities. The survey included over 3500 rooms in more than 1200 buildings; radon concentration was measured by means of passive nuclear track detectors, for two consecutive periods of about six months.

The Research of Fast Prediction Method of Radon Concentration in Environment Air

Wu He-Xi, Liu Yu-Juan, Liu Qing-Cheng, Qin Guo-Xiu

East China Institute of Technology, East China institute of Technology, Fuzhou, Jiangxi, 344000, China

wujing-7758@163.com

From the theory of ^{222}Rn transport in any medium, the equation of radon concentration in environment air can be acquired. The formula was proved practicable by an experiment in a laboratory. Many of field tests during many years, the mean absolute relative error of radon concentration in environment air between mean value of measurement and the value of fast prediction is 8.78%. Finally, our group applied the model to fastly predict radon concentration of environment air, in which the parameter of ^{226}Ra acquired from analytical results about the airborne gamma-ray spectra. The relative error between the two is -11.7%. It was perfectly proved that the transport model can be effectively applied to predict radon concentration in environment air.

^{222}Rn and ^{220}Rn Concentrations Measured Inside Various Green Tea and Coffee Drinks and Resulting Radiation Doses to the Consumers

S. Idane, M.A. Misdaq, Mortassim Azeddine

Faculty of Sciences Semlalia, University Cadi Ayyad, My Abdelah-Semlalia, Marrakech, 40000, Morocco

a.mortassim@ucam.ac.ma

Alpha – activities per unit volume due to radon and thoron were measured inside different green tea and coffee drinks widely consumed by the Moroccan populations, by using a method based on evaluating detection efficiencies of the CR-39 and LR-115 II solid state nuclear track detectors for the emitted alpha-particles. The influence of the water nature and pollution on the concentration of these radionuclides inside the studied green tea and coffee drinks was investigated. Annual commited effective dose due to radon from the ingestion of green tea and coffee drinks by the members of the general public and workers were determined.

^{222}Rn and ^{220}Rn Concentrations Measured Inside Various Olive Oil Samples by using Nuclear Track Detectors and Resulting Radiation Doses to the Consumers

R. Touti, M.A. Misdaq, Mortassim Azeddine

Nuclear Physics and Techniques Laboratory, Faculty of Sciences Semlalia, University Cadi Ayyad, My Abdelah-Semlalia, Marrakech, 40000, Morocco

a.mortassim@ucam.ac.ma

Olive oil is widely used by the Moroccan population for preparing their traditional dishes. In the present work, radon and thoron alpha-activities per unit volume were measured inside different olive oil material samples by using a method based on calculating detection efficiencies of the CR-39 and LR-115 II solid state nuclear track detectors (SSNTDs) for the emitted alpha-particles and measuring the resulting track density rates registered on these detectors. These measurements were completed by an investigation of the radon transfer between soils and plants and between plants and olive oil, and also by the investigation of the radon solubility coefficient inside olive oil. Annual committed effective doses due to radon from the investigation of different olive oil samples by adult members of the public were evaluated.

Study of Inhalation Dose due tu Indoor ^{222}Rn and ^{220}Rn in Bangalore Metropolitan, India

L.A. Sathish[1], K. Nagaraja[2], S. Sundareshan[3], T. V. Ramachandran[4]

[1] *Department of Physics, Government Science College, Bangalore, 560 001, India*
[2] *Department of Studies in Physics, Bangalore University, Bangalore, 560 054, India*
[3] *Department of Physics, Vijaya Degree College, Bangalore, 560 004, India*
[4] *Ex-Environmental Assessment Division, Bhabha Atomic Research Center, Anushakthi Nagar, Mumbai, 450 085, India*

lasgayit@yahoo.com

Radon enters into the atmosphere mainly by crossing the air interface of either soil-air or building materials. The existence of relatively high concentration maintains large gradient between the materials and open air. Solid state nuclear track detector based dosimeters were used for the long-term measurements of ^{222}Rn, ^{220}Rn and their progeny levels in dwellings of Bangalore Metropolitan, India. The study is made to assess the dose effects on humans. It focuses on the concentrations and associated inhalation dose due to ^{222}Rn and ^{220}Rn in dwellings of wide range volume of 30-310 cubic meter. The annual effective dose rate in dwellings of different floors vary between 0.03 – 0.4 and with volume it has the range 0.002 – 0.641 mSv·y^{-1}. Higher concentrations and dose rates were observed in lower volume houses and the houses with granite flooring. The results including background gamma radiation and soil radioactivity are discussed in detail.

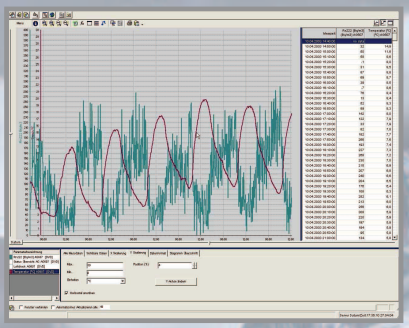
AUTHORS INDEX

SAPHYMO

New WHO reference value – A major challenge to modern Radon measuring technology

ALPHAGUARD

- High sensitivity and fast linear response at 2-2 000 000 Bq/m3
- Long-term stable calibration (5 years guaranteed)
- Direct RS232, Ethernet/LAN interface (optional)
- Multiparameter features
- For all rn measurement applications
- Maintenance-free operation
- Powerful data management and evaluation software DataEXPERT



SAPHYMO

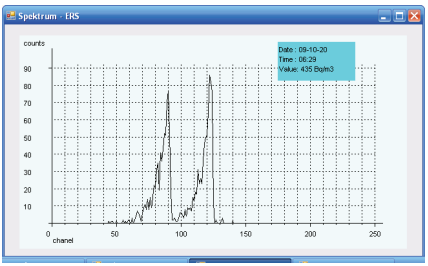
Saphymo GmbH – Heerstraße 149 – D-60488 Frankfurt M.
Ph +49(0)69-976514-0 – sales@saphymo.de - www.saphymo.de

The new Generation of Instruments for the Determination of Radon / Thoron & Progenies

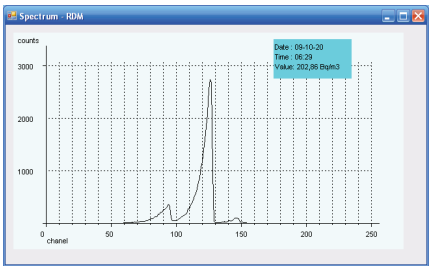
$$\text{Rn-222} \xrightarrow{\alpha} \text{Po-218} \xrightarrow{\alpha} \text{Pb-214} \xrightarrow{\beta} \text{Bi-214} \xrightarrow{\beta} \text{Po-214} \xrightarrow{\alpha} \text{Pb-210}$$

3 8 d — 3m — 27m — 20m — <1sec

The Foto shows the new design of a 2-Channel, real-time and direct reading Radon/Thoron & Progeny Monitor, ERS / RDM-2S



RADON-SPECTRUM



RADON-PROGENY SPECTRUM

TRACERLAB GmbH - Aachener Str. 1354 - 50859 KOELN / GERMANY
Internet: www.tracerlab.com - E-mail: asktracerlab@tracerlab.com