Ministry of Education and Sciences
Nemanjina 22-26, 11000 Beograd
S e r b i a
Project 41 028 activity:

SUBJECT: REPORT on IV ECE Workshop held in Serbia

Dates: 31 October – 1 November 2011
Place: Kragujevac city, Faculty of Natural Sciences, Department of Physics
University of Kragujevac
Title of IV ECE Workshop: Status of work related to radon in Serbia: ongoing projects, international collaboration and plans

I Introduction

The Serbian indoor radon survey is currently based on measurements made in primary schools only within research projects at the Ministry of Education and Science of the Republic of Serbia. The first phase started in August 2008 and has so far included 340 schools in three districts in *South Serbia* (Jablanicki, Pcinjski and Zajecarski okrug). Preliminary results for 124 schools were presented in two published papers (Zunic et al., **Nukleonika (2010**), 55 (4):419 and Carpentieri et al., **Radiation Protection Dosimetry (2011), 145 (2-3), 305-311**), and at two scientific meetings (**International Conference "Radon in Environment 2009"**, 10-14 May, 2009, Zakopane, Poland, and **6th Conference on Protection Against Radon at Home and Work**, 13-17 September 2010, Prague, Czech Republic) and at **III ECE Workshop 2010: "First results of the Serbian Radon (Risk Mapping) Survey"**, 5-7 July 2010, Sokobanja, Serbia). The complete results (including those of the 216 remaining schools) are presented at this meeting. The radon concentration measurements have been carried out in cooperation with an Italian research team led by the Italian National Institute of Health, Rome, Italy (Dr Francesco Bochicchio, Head) and with Dr Peter Bossew from the German Federal Office for Radiation Protection, Berlin, Germany.

This IV ECE Workshop was designed as a continuation of the III ECE workshop also organized by Dr Zora S. Zunic, from ECE Lab, Institute of Nuclear Sciences Vinca, in July 2010, Sokobanja, Serbia. There the following issues were analyzed and discussed:

- summary of design, methodology of sampling and field survey in schools of Serbia;
- radon concentration measurement methodology (detector etching and track counting, uncertainty analysis, quality assurance);
- logistical difficulties and how to proceed with the survey;
- to which degree can radon measurement in schools be considered representative of the population exposure to radon in dwellings?
- how to evaluate the relationship between radon measurement in schools and in dwellings;
- first evaluation of spatial distribution of radon concentration based on the available data.

At the IV ECE Workshop meeting the following issues were considered:

- Serbian schools issue –the results of indoor radon in schools of 13 communities:

All results for 340 schools in three South Serbian districts and their 13 communities were presented;

- Sokobanja issue - indoor radon in houses –"onion model", evaluation of the representativeness of radon measurements in schools:

The discussions on how to use the radon (Rn) concentration measurement results in schools to estimate Rn concentration in dwellings led to a proposal of a regional project in Sokobanja, aimed to investigate if, and how, a relation between Rn levels in schools and dwellings can be established. Later in 2010, the Vinca team in cooperation with Sokobanja administration started to implement one of the two main components of the proposal, i.e. the radon concentration measurements in dwellings located close to previously measured schools (so called "onion" model by Dr Peter Bossew). So far partial results of indoor radon concentrations in 43 houses had been available, which were discussed at this IV ECE Workshop meeting. The findings may lead to tuning the further course of the project. The other main part of the proposal, i.e. the **evaluation of the representativeness** of radon measurements in schools with respect to the population exposure in dwellings, has yet to be carried out, aiming to deploy Cr 39 detectors in all 105 houses in Sokobanja community as we agreed upon during the IV ECE Workshop meeting.

The results of the indoor radon investigation over 340 schools with particular aspect of evaluation on its representativeness of the houses is subject of a potential PhD thesis under the working title: *Map of radon risk in some of the rural areas in Serbia based on the measurements of indoor radon in schools*, at the Faculty of Natural Sciences, Department of Physics University of Kragujevac, (with mentor Prof. Dr Nikezic Dragoslav, co-mentors Dr Z.S. Zunic, Dr F. Bochicchio, Dr P. Bossew, Dr C. Carpentieri, and candidate Mr Sci Olivera Cuknic.).

- Kosovo issue: indoor radon and thoron in the houses

A second project, running in parallel, is a measurement survey in residential houses in Kosovo that has been started with passive method since 2007 with Solid State Nuclear Track Detectors (SSNTDs). In this project, like in the houses of the Sokobanja project, beside measuring radon gas, Thoron gas and also Thoron (Tn) and Rn/Tn progeny are assessed using technology from India (Dr Y. S. Mayya, Head, Dr Rosaline Mishra). So far indoor radon and thoron concentrations have been measured in 110 houses of North and Central Kosovo and Prizren region. As in the case of Sokobanja houses and in other regions of Serbia, it was concluded that these values would contribute to the **integration of Serbian data into the European Indoor Radon Map,** and it was pointed out that it is necessary to collect all results from Kosovo and Metohija on indoor radon survey. (Z.S. Zunic has to contact authorities responsible for the measurements in Albanian houses). All these measurements are subject of a potential PhD thesis under working title: *Radon and Thoron Concentration Activities Distribution in the Rural Houses at Kosovo and Metohija – A*

Correlation with the Contents of Natural Radionuclides in Its Soil, at Faculty of Natural Sciences, Department of Physics University of Kragujevac, with mentor Assoiciate Professor Dr Nenad Stevanovic, co-mentors Dr Z. S. Zunic, Prof. Dr Nikezic D., Doc. Dr G. Milic, Dr F. Bochicchio, Dr P. Bossew; candidate Ljiuljana Colic-Gulan)

- Banjaluka city in Republic Srpska – indoor radon in schools and houses

This issue concerns the radon survey in the schools of Banjaluka city in Republic Srpska. The application of active and passive methods for measuring the indoor radon concentrations in 25 schools of Banjaluka city is currently in progress. Since April 2011 a radon survey has been carried out in 10 schools of Banjaluka town in the period of four months (April-August 2011), being the first preliminary measurements of indoor radon concentrations ever made by means of active and passive methods in this city. The average indoor radon concentration activity results after indoor radon were continuously monitored by RAD 7 instrument. Seven-day measurements were made in eight schools with normal working regime and in two schools during five days, after the schools were closed due to summer holiday. Out of ten schools investigated, the high indoor radon concentrations levels were found in four ones. The results for short–term measurements by passive gammadata detectors were also provided. These preliminary results presented at the IV ECE Workshop meeting served as base for planning future activities, i.e., it is agreed upon that beside the schools, where also SSNTDs were deployed, in a number of 50 houses randomly distributed, the Cr 39 detectors and Rn/Tn progeny detectors will be deployed. Also in some schools the application of active method will be repeated due to "the precision in field conditions". The detectors will be kindly supplied by Dr Francesco Bochicchio. The results will be subject of a potential Ph D thesis under the working title: *The Results of the Application of Active and Passive methods in determination of indoor radon concentration activity in 25 elementary schools and 50 houses of Banjaluka City,* at Faculty of Natural Sciences, Department of Physics University of Banja Luka, with mentor Dr P. Kolarz, co-mentors Dr Z.S. Zunic, Prof Dr B. Predojevic, University of Banjaluka city.

- Undergorund Low Level Activity Laboratory (ULLAL) in the Institute of Physics,Beograd

The issue is devoted to the description and measurements of indoor radon in underground low-level laboratory in the Institute of Physics where continuous indoor radon measurements have been carried out for several years. The results of the short-term and long-term measurements showed that in spite of having implemented a system for radon reduction, there is still one-year and one-day clear periodicity in the radon behaviour. At the IV ECE Workshop meeting possible mechanisms of the Rn dynamic were discussed, and how also the residual Rn levels could be reduced. There was agreement about the necessity to investigate in much more details the possibly complicated relation between Rn and meteorological parameters such as temperature, atmospheric pressure and humidity. This appears also to be a potential subject for a PhD thesis: *Comparison of the sensitivity of SSNTDs in Underground Low Level Activity Laboratory and in the real conditions,* at the Faculty of

Natural Sciences, Department of Physics, University of Beograd, with mentor Dr Vladimir Udovicic and co-mentors Dr Z.S. Zunic, Dr P. Bossew)

- Other matters:

This meeting also gave the possibility **for several lectures** on the following topics:

- The log-normal mystery of radon (P. Bossew);
- The relation on radon and ions (P. Kolaraz)
- The elements of radon epidemiology (F. Bochicchio),
- The new regulations of IRPA (F. Bochicchio)
- Fukushima accident – influence over Europe (P. Bossew) – the FIRST presentation of the integrated results of several laboratories around Europe; especially the students participated.

There was a plenty of discussions and very useful new professional contacts, and it was suggested that participants may find a way to apply for a FP7 project.

II, TITLES and short SUMMARIES of the lectures given on Day 1, 31 October 2011 and Day 2, 1 November 1 2011:

1.1. Radon measurement in primary schools of 13 Serbian municipalities (C. Carpentieri, F. Bochicchio)

- **Summary**: Results of radon concentration measurements in 327 primary schools (98% of all primary schools in the selected 13 municipalities) were presented, together with an analysis of variability between schools, within schools, between different floors and between different usages of rooms, as well an analysis of seasonal variability.

1.2. Radon measurements in primary schools of 13 Serbian municipalities: issues on representativeness (F. Bochicchio, C. Carpentieri)

- **Summary**: Different possible uses of the measurements in primary schools were presented, with particular emphasis on specific representativeness issues.

2.1. "Onion model" - Sokobanja school project: rationale, design, first results (P. Bossew)

- **Summary:** In order to investigate whether the results of the school survey can be used for estimating concentrations in dwellings a small project was designed in Sokobanja district. A number of geo-referenced measurements in selected dwellings will be performed (some results are already available, see 2.2) according to a spatial scheme, aimed to reveal such relationship. The spatial variability of the controlling geogenic Rn potential is tentatively accounted for by allocating the dwellings in circular zones around the schools (hence the term "onion design"). First, very

preliminary results based on a few measurements indicate the existence of a relationship, but significance is yet poor.

2.2. Radon measurements in Sokobanja houses (C. Carpentieri, F. Bochicchio)

- **Summary:** Results of radon concentration measurements in 43 dwellings of Sokobanja community obtained with two different types of detectors were presented and compared. Although no significant systematic difference was observed, results show differences which are probably due to high random fluctuations due to the low level of measured radon concentration.

3. Integration of Serbian data into the European Indoor Radon Map (P. Bossew, V. Gruber, T. Tollefsen)

- **Summary:** The ongoing project of a European Indoor Rn Map includes contributions from 23 European countries by October 2011. It is natural to include also Serbian efforts of Rn surveys into this endeavour. The state of the European Rn map was presented and some problems of data harmonization were discussed. The Rn map is part of the larger project of a "European atlas of natural radiation", whose next step, currently in the stage of developing techniques and procedures, is the map of geogenic Rn. Also its state was presented together with specific technical problems which are still in the discussion phase.

4. An overview of radon measurements in Kosovo (Z.S. Zunic**)**

- **Summary**: An overview of radon survey over periods in Kosovo and Metohija has been given since 1983 with wider interpretation on Gornja Stubla area, which has been identified as a region with relatively high level of natural radiation. The new indoor radon and thoron filed campaign results were presented, particularly regarding the potential of a Ph D thesis. The papers published on all these results have been presented in chronological order.

5. New approaches of International Radiological Protection association (IRPA); Some elements of radon epidemiology for physicists (F. Bochicchio)

- **Discussion:** New approaches of the International Radiological Protection Association (IRPA) – F. Bochicchio (action level, reference level, regulations on building material, remediation methodologies, potential of advanced and multidisciplinary education at physics and medical studies or even earlier through secondary schools).

6. Radon: the log-normal mystery (P. Bossew)

- **Summary:** Many researchers have noted that Rn related variables are often spatially distributed approximately log-normally. In this presentation this is quantitatively investigated for Austrian point data and European cell average data of indoor Rn concentration. As a result the LN hypothesis holds true with high probability over a large spatial range, with exceptions due to local peculiarities in the spatial Rn field. Also possible explanations of the phenomenon are discussed. In particular a model borrowed from statistical physics (in recent years also applied in geochemistry) is presented, called multiplicative cascade, which is able to generate fields with analytical properties which are very similar to the ones observed with empirical Rn data.

7. Present status of the radon and thoron experiments in the Underground Low-Level Laboratory, Belgrade (V. Udovicic)

- **Summary:** The presentation shows the radon and thoron measurements in the Low-Background Laboratory for Nuclear Physics, Belgrade, Serbia. The results of the short-term and long-term measurements are pointed out that in spite of the implementation of a system for radon reduction there is still one-year and one-day clear periodicity in the radon behaviour. Issues arising from the preliminary results of the short-term and long-term radon measurements in the underground low-level laboratory are:
  - short-term versus long-term radon measurements in the field of the low-level radon concentration,
  - thoron mystery in the underground low-level laboratory?
  - comparison of the different passive methods for radon and thoron detection in the low-level and real conditions.

8. Measurements and characterisation of waterfall generated ions (P. Kolarz)

- During a 4-year field campaign of waterfalls physical characterization due to their medical effects – more than 20 waterfalls in Austrian Alps were investigated. Characterization of spatial and size distribution of ions generated by waterfalls is shown.

9. **Fukushima accident influence on Europe – comparison with Chernobyl accident** (P. Bossew)

- **Summary:** About 10 days after the Fukushima reactors failed as a consequence of a very strong earthquake and tsunami, radioactive releases were also observed in the air over Europe, and consequently in environmental media, however in small traces compared to the situation in Japan. We present time series of observations and maps of maximal and cumulative ^{131}I concentrations in air over Europe as well as probabilistic maps. Also levels in rainwater, plants and milk are shown, and some estimations of doses given, which turn out negligible in Europe. For comparison, a few data from the Chernobyl accident are shown. It is further demonstrated how ratios between different radionuclides which were observed in air can be used to draw conclusions about the states of the affected reactors, and about release conditions.

10. Presentations of the Radon Kragujevac researcher group-RADKRAG (J. Stajic , D. Nikezic, N. Stevanovic, B. Milenkovic, V. Markovic)

- **Summary:** An analytical consideration of the geometrical efficiency of a circular detector for particles with a finite range, emitted from a point-like source was presented. Several different cases were determined, depending on the particle range, radius of the detector and the position of the source in respect to the detector. These cases were analyzed separately and different expressions for calculating the hit probability were obtained for each of them. The same problem was investigated taking a critical detection angle into account. Incident-energy dependence of the critical angle was assumed. The method was applied to calculating CR-39 detector

efficiency. Results were compared with Monte Carlo calculations. (J. Stajic and D. Nikezic):

- **Summary:** Behaviour of radon and its progeny in the room was investigated. Recoil factor of the radon progeny from the aerosols was estimated and Jacobi room model for radon and thoron progeny in the room according to three modal aerosols distribution was developed. The Jacobi room parameters were calculated using the Brownian motion model and their relationships were found for turbulent airflow in the room. Radon diffusion was considered in diffusion chamber by Monte Carlo method where non-uniform deposition on the chamber wall was found. The stopping power was calculated by modelling target and projectile as quantum harmonic oscillators and influence of electron motion in the target atom on the projectile energy loss was investigated. Absorbed fractions of electrons in sensitive layers of HRT were calculated and analytical model of bifurcation region was developed. The computer code for neutrons simulation in the CR39 detector was developed and it was applied for calculation of parameters of the track in same and opposite directions (N. Stevanovic)

- **Summary:** Our group developed FORTRAN program Neutron_CR-39.F90, which enables neutron simulation trough CR-39 detector and calculation of track profiles after etching. The program Neutron_CR-39.F90 contains subroutine Neutron.f90 for neutron simulation and subroutines Trackfdmsame.f90 and Trackfdmback.f90 for the calculation of created track profiles after detector etching in the same and reverse direction, respectively. Some tracks will be etched from the point where the particle was created in the direction of the particle motion – this is direct etching. Other tracks will be etched from the point where the particle was stopped or from where it exited from the detector, in opposite direction of particle movement – this is the etching in reverse direction. The outputs of the program are:
  (1) the file *Protons Am-Be.dat* which contains data of recoiled protons as: recoiled angle α, in respect to the X axis; coordinates X of starting and stopping point; initial and deposited energies of protons
  (2) deposited energy of recoiled protons per number of visible tracks, Ed (keV/track)
  (3) number of visible tracks per number of incident neutrons, Nn (tracks/n). (B. Milemkovic)

- **Summary: Beta and Gamma Dose Assessment due to Radon Short - Lived Progeny:** Great deal of work has been devoted to determine doses from alpha particles emitted by ^{222}Rn and its progeny. In contrast, contribution of beta particles and following gamma radiation to total dose has been neglected by most of the authors. The present work describes a study of the detriment of ^{222}Rn progeny on the humans due to internal and external exposure. Doses and DCF were determined for beta and gamma radiation in main organs and remainder tissue, taking into account ^{222}Rn progeny ^{214}Pb and ^{214}Bi. For internal exposure

radon progeny were distributed in the lungs and fro external exposure progeny were distributed atmosphere of standard room for ORNL phantom in the middle of the standard room with dimensions 4×5×2.8m. DCF was found to be 13.3 and 5.83 μSv/WLM for internal and external exposure respective. Skin and muscle tissue from remainder receives largest dose. Total doses received in all main organs and remainder tissues were obtained by summing up the doses from external and internal exposure and DCF was found to be 19.13 μ*Sv/WLM.* (Vladimir Markovic):

RESUME of the presentations with corresponding titles:

I

• **Summary and evaluation of the results of indoor radon survey on 327 schools in 13 communities in three districts of Serbia** : Jablanicki, Pcinjksi and Zajecarski
• 2 presentations
1. Radon measurement in primary schools of 13 Serbian municipalities (C. Carpentieri, F. Bochicchio)
2. Radon measurements in primary schools of 13 Serbian municipalities: issues on representativeness (F. Bochicchio, C. Carpentieri)

II

• **The "onion" model" to compare measured indoor radon in dwellings and primary schools of Sokobanja community**
• 2 presentations
1. Sokobanja "dwelling vs. school" project: rationale, design, first results (P. Bossew)
2. Radon measurements in Sokobanja houses (C. Carpentieri, F. Bochicchio)

III

• **Potential of inserting indoor radon results of SERBIAN dwellings so far into EU Atlas of radon risk maps**
• 1 presentation
1. **Integration of Serbian data into the European indoor Radon map** (P. Bossew, V. Gruber, T. Tollefsen)

IV

• **Radon in Kosovo: history of radon surveys, publications, current investigations on indoor radon, potential Rn risk mapping**
• 1 presentation
1. An overview of radon measurements in Kosovo (Z.S. Zunic)

V

• **Discussion: new approaches of International Radiological Protection association IRPA**
• 1 presentation
1. **Some elements of radon epidemiology for physicists** (F. Bochicchio)

VI

• **Radon: the log-normal mystery**
• 1 presentation
1. The log-normal mystery (P. Bossew)

VII

• **Description, activity and results of the measurements of indoor radon at Under Level Low Activity Laboratory (ULLAL) in the Institute of Physics**–Beograd, Serbia
• 1 presentation
1. Present status of the radon and thoron experiments in the Underground Low-Level Laboratory, Belgrade (V. Udovicic)

VIII

• **Radon and Ions**
• 1 presentation
1. Measurements and characterisation of waterfall generated ions (P. Kolarz)

IX

• **Fukushima accident**
• 1 presentation
1. Fukushima accident influence on Europe – comparison with Chernobyl accident (P. Bossew)

X

• **Presentations of RADKRAG (radon Kragujevac research team):**
• 4 presentations
1. J. Stajic and D. Nikezic: Geometrical efficiency of a circular detector for particles with a finite range, emitted from a point-like source
2. Use of CR-39 detector in neutron detection and dosimetry (B. Milenkovic)
3. Short presentation of some results of **Rad**on **Krag**ujevac (**RADKRAG**) research team (N. Stevanovic)
4. Beta and Gamma Dose Assessment due to Radon Short Lived Progeny (V. Markovic)

CONCLUSIONS of the IV ECE Workshop:

TASKS:

1. Finalize Sokobanja dwellings indoor survey – houses within villages according to "onion model";
2. Start to investigate in houses beside schools in Republika Srpska, according to the "onion" model - scheme of P. Bossew; the Cr 39 detectors has been promised by Dr F. Bochicchio to be sent in due course;.
3. Dr Meleq Bahtiari to be asked to add his GPS coordinates and Concentrations of indoor radon in houses at Kosovo and to send to P. Bossew. to contribute to indoor radon mapping of Europe;
4. Gornja Stubla and Kalna to find out the GPS coordinates according to existing schematic maps and to Google Earth and to send a table to P. Bossew;.

5. Z.S. Zunic to ask about the lung cancer cases number and its distribution over regions in Serbia with indoor radon concentrations distribution;
6. Conclusion – possibility of joint action regarding FP7
7. Contact with Dr C. Cosma (University Cluj, Romania) about possible bilateral cooperation (University Cluj, Romania)
8. It was agreed between participants that it should be very useful to continue the next year with this tradition (foreseeing a V ECE Workshop?) with the new results and approaches.

RESEARCH PARTICIPANTING INSTITUTIONS in IV ECE Workshop:

1. Electrochemical Laboratory (ECE LAB) , Lab. for Radiobiology and Molecular Genetics, Institute of Nuclear sciences „Vinca“, Beograd, Serbia;
2. Faculty of Natural sciences, department of physics, University of Kragujevac, Kragujevac, Serbia;
3. Italian National Institute of Health, Rome, Italy,
4. Federal Biro for Radiation Protection, Berlin, Germany;
5. Faculty of Natural Sciences, University of Pristina, Kosovska Mitrovica, Serbia;
6. Institute of Physics, University of Belgrade, Pregrevica 118, RS-11080 Belgrade, kolarz@ipb.ac.rs, Beograd, Serbia;
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8. University of Salzburg, Department of Materials Research and Physics, Division of Physics and Biophysics, Hellbrunnerstr. 34 A-5020 Salzburg, pierre.madl@sbg.ac.at,

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The Organizers:

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- Prof Dr Dragoslav Nikezic, Full professor, Dean of the Faculty of Natural Sciences at University of Kragujevac, Kragujevac, Serbia

Co-organizers:

- Dr Vladimir Udovicic, Institute of Physics, Beograd, Serbia
- Dr Predrag Kolarz, Institute of Physics, Beograd, Serbia
- Dr Peter Bossew, BFS, Berlin, Germany
- Dr Francesco Bochicchio, Italian National Institute of Health, Rome, Italy

Participants:

Participants to the meeting are experts who are involved in the ongoing Serbian Rn survey and researchers and representatives of Serbian scientific institutions, who are involved in assessment of environmental radioactivity.

1. Dr Peter Bossew, BfS Berlin, Germany
2. Dr Francesco Bocchicchio, National Institute of Health, Rome, Italy;
3. Dr Carmela Carpentieri, National Institute of Health, Rome, Italy;
4. Dr Dragoslav Nikezic, University of Kragujevac, Serbia, and University of Hong-Kong;
5. Dr Dragana Krstic, University of Kragujevac, Serbia
6. Dr Nenad Stevanovic University of Kragujevac, Serbia
7. Dr Vladimir Markovic, University of Kragujevac, Serbia
8. Biljana Milenkovic, Ph D candidate, University of Kragujevac, Serbia
9. Jelena Stajic, Ph D candidate University of Kragujevac
10. Dr Vladimir Udovicic, Institute of Physics, University of Beograd , Serbia;
11. Dr Predrag Kolaz, Institute of Physics, University of Beograd ,Serbia
12. Dr Gordana Milic, University of Pristina, Kosovska Mitrovica
13. Ljiljana Colic-Gulan, Ph D candidate, University of Pristina, Kosovska Mitrovica
14. Jelena Filipovic, Ph D candidate ECE lab, Institute of Nuclear Sciences Vinca
15. Dr Zora S. Zunic, ECE lab, Institute of Nuclear Sciences, Vinca.

and students.

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