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Radon laboratory for secondary schools

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Summary. — The "nuclear issue" was a taboo for a long time in Italy. A way to approach this theme, to make the public more trusting of nuclear issues is to discuss radioactivity and ionizing radiation starting from young people. An experimental activity that involves secondary school students has been developed. The approach is to have students engaged in activities that will allow them to understand how natural radioactivity is a part of their everyday environment. This would include how radiation enters our lives in different ways, to demonstrate that natural radioactive sources found in soil, water and air contribute to our exposure to natural ionizing radiation and how this exposure affects human health. Another markpoint is to develop a new technique for teaching physics which will enhance scientific interest of students in applications of nuclear physics in both environmental and physical sciences and to train their teachers on these subjects.

1. – Description —Introduction

A lack of information will lead to unwarranted fears, which will distort the risks we take in everyday life. In other words the subjective perception —*sensation*— of the risk does not usually correspond to the objective and real risk of human activity [1]. Our perception of radioactivity is often misleading because of the lack of accurate information [2]. One result of this misinformation has been the linkage between nuclear weapons and nuclear power plants (NPP). In the last 50 years NPP for civil uses has significantly fewer casualties than any other source of energy, however, because public opinion is driven by emotions rather than rational-knowledge–based views, nuclear power's association with nuclear weapons has contributed to its lack of acceptance in many places throughout the world. The fear, anger and distrust following the accident at Fukushima shows that communication is still a major problem.

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Fig. 1. – INFN Sections involved in the project in 2018.

Moreover:

- the radioactivity and the ionizing radiations are perceived as an imperceptible and therefore subtle danger;
- there is a lack of information on environmental radioativity;
- there is a lack of clarity about how physics can help us to understand the environment surrounding us, the life science and the human health.

On this basis several Physics Departments with Radon Laboratory inserted in the Lauree Scientifiche Project funded by the Italian Ministery of University and Scientific Research (MIUR) and Sections of the National Institute of Nuclear Physics (INFN) with RADIOLAB Project [3], want to contribute to: carry out an effective action to spread scientific culture, and in particular about nuclear physics, through the involvement of high school students in environmental radioactivity measurements; promote the knowledge of the territory, with particular attention to environmental radioactivity and develop new ways of training and disseminating knowledge, which is conveyed by the students themselves. This activity, that started about 15 years ago, gives to the students and the teachers of the Italian secondary school system the opportunity to discuss and to experiment with nuclear related experiences. The students were provided basic but correct information, with the possibility to experiment as an added benefit. Moreover, this program offers the students the opportunity to understand the meaning of a research activity [3-7].

Figure 1 shows the INFN Sections involved in the project in 2018.

Depending on local situations and the specific experiences of the students, several approaches were used. However, the collaboration among the schools was an essential element in the program's success. The common core ideas are: a) to provide the students a furnished laboratory at their school so that they can measure the natural component of the radioactivity that surround us. In this exercise the measurement of the ^{222}Rn concentration is particularly well suited; b) to show the different types of radiations including ionizing radiations and how they each relate to the other; c) to demonstrate how easily ionizing radiations can be measured; d) and to prove the fun a student can feel from discovery and detecting ionizing radiation in the environment.

In this paper the experience of Regione Lombardia reality has been reported in more detail.

2. – Materials and methods

2˙1. *Methodology.* – The measurements of environmental radioactivity are particular suitable for the dissemination of knowledge in Physics in the field of ionizing radiation. They also allow to understand that the average collective exposure to the world 's population is primarily caused by natural sources from cosmic and terrestrial radiation while the radiation sources produced by man contribute with a negligible amount.

One method which assists students' understanding of this concept is the construction of their own school laboratory where they will have the opportunity to measure natural radioactivity by themselves [8].

The aims of the project are: a) the students become confident with nuclear science with a correct information about the problem of the radioactivity; b) are involved in physics measurements, in handling equipment, in data analysis, in result report; c) are stimulated to know the environment where they live; d) to enrich and re-evaluate the multidisciplinarity of the scientific knowledge with the integration of various aspects of science; e) to highlight the links between science and society.

The phases of the process follow the typical research scheme and include, after a preliminary step related to learn about topics on basic nuclear physics and in particular on radioactivity, that the students by themselves, with the help of their teachers and university tutors a) set up the instrumentation and detectors; b) organize the measurement campaigns; c) carry out the measurements and the data analysis. At the end of each year, in an annual meeting, the students present, through talks, posters and other forms of mass communication, the results and their remarks and conclusions at the Physics Department.

The Laboratory wants to be not just a physical place but the METHOD of "KNOW" through the "KNOW-HOW". This approach is a new way to teach and learn, to improve communication, interaction and discussion, with a laboratory where students are directly involved in experimental activities.

2˙2. *Experimental.* – On the basis of the experience, it was found that the project needed to be distributed over two scholastic years. In Regione Lombardia were directly involved in this project about 1400 students of 47 different schools. Figure 2 reports the distribution of the schools in the different provinces (b) and the percentage of the kind of schools involved (a). Since 2017 the Themistokli Germenji School of Korce in Albania asked to be involved and was included in the project.

After a training on the different detection techniques, active and passive systems, short-and long-term measurements, nuclear training kits are distributed to the students with the expectation that they would set up a small-scale radiation laboratory. The kits distributed to the Regione Lombardias schools include passive dosimeters CR-39 (polycarbonate plastic, sensitive to alpha particles), small plastic boxes to be used as

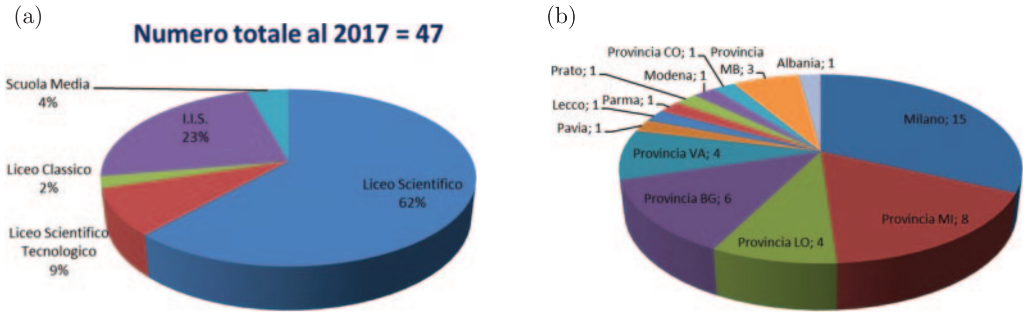


Fig. 2. – Distribution of the schools involved in the Project under the UNIMI and INFN-MI supervision. (a) Percentage of the different kind of schools; (b) schools as distributed in different provinces. Note that since 2017 also a High School in Albania is included.

expansion chambers, a fryer to be used as thermostatic bath to develop the dosimeters, and a cheap optical microscope with a simple webcam designed to be interfaced with a standard PC.

The students themselves prepare the dosimeters and placed the detectors in the diffusion chambers. Afterwards they started the survey procedure positioning the dosimeters and filling data sheets with information on the sampling sites and radon devices (device code, period and place of exposure, device position within the room, etc.). After the CR-39 dosimeters exposure (at least 3 months, but they can be exposured for 6 or 12

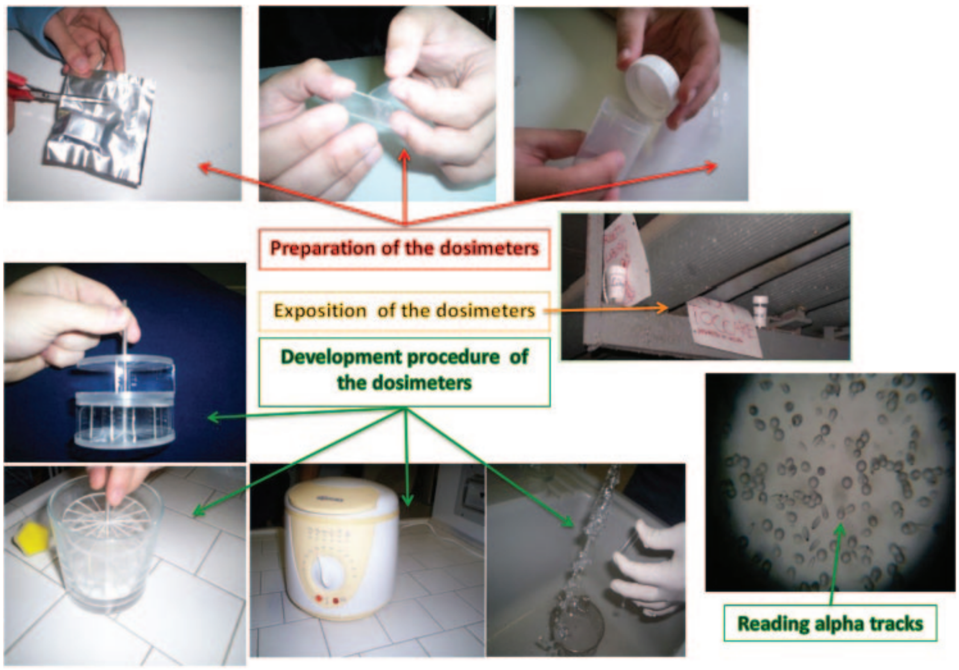
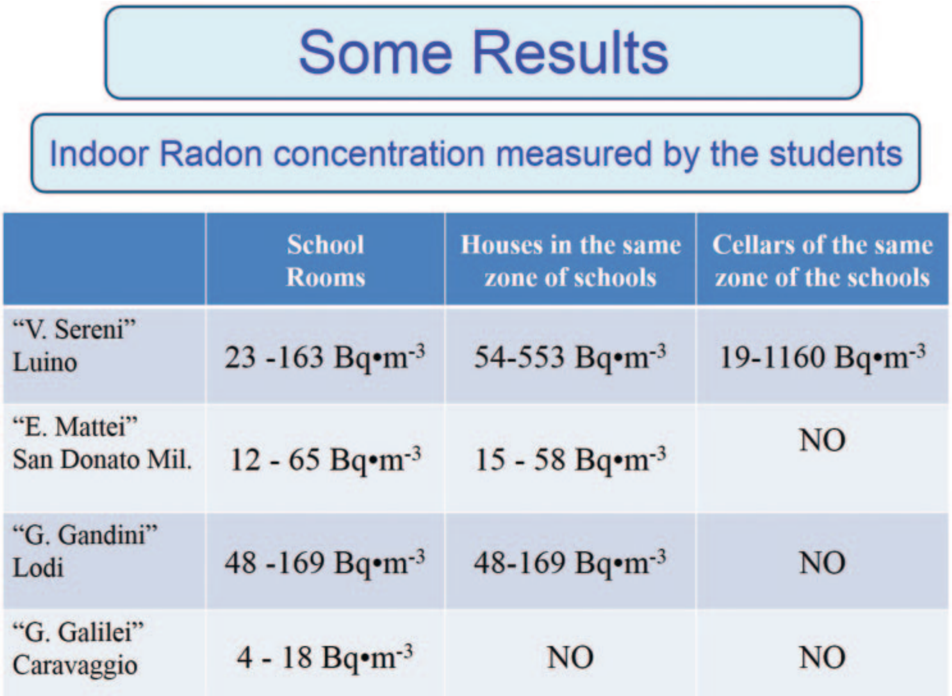


Fig. 3. – Different steps in which students are involved: preparation of dosimeters; positioning CR-39 inside the diffusion chamber to be exposed for the measurements; chemical etching and reading the detectors by means of an optical microscope.

months), the students are involved in the etching procedure, with a 6.25 M NaOH solution at 85 °C for 6 h, in order to enlarge the alpha tracks, and on CR-39 reading at a microscope equipped with the webcam connected to a personal computer. In this way the tracks are counted to determine their density and then, through a conversion by Monte Carlo code, the radon concentration values in $Bq\,m^{-3}$ are obtained. Finally with the help of their teachers, students prepare a report like a scientific publication, and at the end of the year present in the Radon Meeting at the Physics Department the results of their activity. Typically, these values are compared with the results obtained: a) by gamma spectrometry of ^{222}Rn chain daughters (^{214}Pb, ^{214}Bi, whose activity is accumulated in charcoal canisters exposed for shorter time) and/or b) with continuous measurements of alpha activity by ZnS(Ag) solid scintillation chamber. Through this method students are challenged to reach a better understanding of the different measurements techniques that can be obtained through more comprehensive data interpretation.

In fig. 3 are summarized the different steps in which the students are directly involved for the determination of the ^{222}Rn concentration by the CR-39 technique.

From a didactic point of view among the different radiation detection techniques the ones proposed in this Laboratory are of particular interest. In fact with the passive dosimeters like CR-39 the students can "see" and count the tracks that alpha particles leave in the plastic support, with gamma spectrometry they can display, on the gamma spectra, the contributions of the radionuclides present in environmental matrices and they can make the analysis by themselves.



Some Results

Indoor Radon concentration measured by the students

	School Rooms	Houses in the same zone of schools	Cellars of the same zone of the schools
"V. Sereni" Luino	23 -163 Bq•m^{-3}	54-553 Bq•m^{-3}	19-1160 Bq•m^{-3}
"E. Mattei" San Donato Mil.	12 - 65 Bq•m^{-3}	15 - 58 Bq•m^{-3}	NO
"G. Gandini" Lodi	48 -169 Bq•m^{-3}	48-169 Bq•m^{-3}	NO
"G. Galilei" Caravaggio	4 - 18 Bq•m^{-3}	NO	NO

Fig. 4. – Some preliminary results of the indoor radon concentration values in schools and dwellings.

3. – Results and discussion

It is clear that the experimental activities relative to measurements and data analysis were the most exciting stages for the students.

We report in fig. 4 as examples some results that are not exaustive from the survey carried out, involving students related to UNIMI and INFN-MI.

The measurements with CR-39 are carried out in accordance with the Italian Radioprotection Law, so the data collected will be used for the radon concentration mapping of the school buildings, as required by the Legislation. Moreover the significant amount of scientifically valuable data contributes, for Regione Lombardia, to the national database [9].

The students, motivated by their curiosity, carried out measurents also in their houses and in different places other than the classrooms of the respective schools, like rooms of the town hall buildings, caves, archeological sites ... Two examples are reported in fig. 5. In this way the educational result is amplified: on the one hand the students achieved a higher level as regards the empowerment for these issues because they have to explain to people that have no physics knowledge, like the components of the family or Competent Authorities responsible of the sites, in order to be accepted and, on the other hand, there is a spread of information among the population that knows little about these issues, making it more aware about these themes.

The students understand the relationship between the world of school and their families, science and society so as to recognize the social value for scientific knowledge.

The satisfaction expressed by the students and the teachers regarding this project and the way to approach the Physics subject is confirmed by the number of the schools that ask to participate, which increases year by year and also by the schools already participating which continue the activity, thus establishing a virtuous cycle.

3·1. *Some implications and actions related to the project.* – Some collateral positive effects of this project are:

– teachers' formation is updated, through their active involvement on modern physics issues, now introduced in the ministerial programs of the last year of high school;

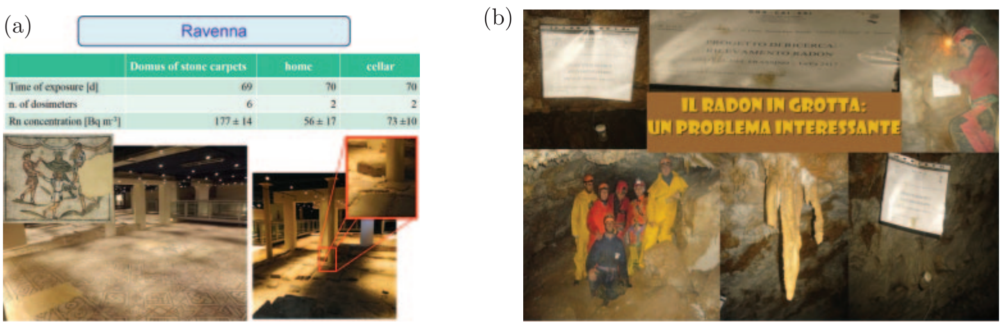


Fig. 5. – Some examples of different sites choosen by the students, motivated by their curiosity, in respect to dwellings or classrooms of the schools. (a) Radon concentration measurements in italian archeological site "Domus of Stone Carpet" in the city of Ravenna. (b) Radon concentration measurements in caves near the city of Varese, where the values found were very high with respect to the houses. The students tried to find an explanation and correlation with the geomorfology of the site.

– collaboration in the revision of scholastic programs with the introduction of elements of nuclear physics and radioactivity integrated with mathematics, chemistry, biology, geology, legislation, . . .;

– scientific dissemination: the same participating students convey environmental radioactivity information in their school, family and general public environment;

– this iniziative gave the opportunity to the students involved to partecipate to many national and international scientific competitions, many of them winned by our students, that have exported abroad the approach of the project to make people aware in the subject of radioactivity.

– last but not least, in the next future, Italy, as a Nation of the EU, has to transpose in a new Italian Radioprotection Law, the Council Directive (2013/59/Euratom) on Basic Safety Standards, BSS, for protection against the dangers arising from exposure to ionising radiation including exposures to radon in dwellings, buildings with public access and workplace. So as well summarized by Bochicchio [10], in the 2013/59/Euratom Directive, protection against indoor exposures to radon in both workplace and dwellings is clearly regulated. Requirements for radon in workplace are much more tightening than in the previous Directive, and exposures to radon in dwellings are regulated for the first time in an EU Directive. Pending the entry into force of the new legislation it is necessary to:

– reinforce the Health Physics and Radiochemistry branch at the University;

– establish, in collaboration with other partners, different initiatives of training for all the figures involved in the Directive. One of this, is the proposal of a summer school in Italy for students but open also to future professionals who will want to "get into the business" of radon concentrations measurements, in order to train on the different measurement techniques and systems;

– collaborate by providing help on the use of equipment;

– educate the teachers of High Schools to raise the awareness of their students about these types of issues.

4. – Conclusions

The project presented above arouses strong interest and the desire to understand more deeply a subject like radiaoctivity, that in general is unusual.

This kind of activities represents a successful example of dissemination of the environmental radioactivity knowledge, based on the direct involvement of students and their physics teachers in experimental activities in this specific topic.

An experimental activity is a good way to provide for an adequate scientific background and starting from the measurement of natural radioactivity is a good way for the students to approach the nuclear theme on a more rationale basis.

Through the activities of the project it is possible to recognize interdisciplinary connections between different scientific disciplines related to radioactivity (geology, chemistry, biology, mathematics and computer science . . .).

Moreover through this project also the teachers carry out a training or refresher course on these subjects.

The implementation method also leads to the dissemination of environmental radioactivity topics also outside the school environment. The awareness of the presence of an environmental radioactivity of natural origin ensures that students, their teachers and their families become familiar with these issues.

Scientific communication, teaching and research are integrated, putting in place actions of training orientation through a process that follows the phases through which a research work evolves.

The participation of the schools to this project also allows to carry out monitoring activities of indoor radon and radionuclides in the environment, both of natural and anthropic origin.

More generally, activities using ionizing radiation become each day more and more employed in every field of our life. The real risk, is related to the loss of expertise: the ageing of the workforce, limited prospects for new build and moratoria in a number of countries on the use of nuclear energy are all aspects that impact the level of skills and competence across the whole nuclear sector, particularly in the West Countries and dramatically in Italy.

Key indicators of the nature of this problem are: declining university enrolment, closure or dilution of university departments offering nuclear education and training, demographics of the workforce resulting from retirement over a relatively short period with little or no replacement planned, major reductions in research capacities as the industry matures, reducing funding for experimental research and closure of dedicated experimental facilities, which has been accelerated by growing social distrust of experiments involving radioactive materials. The real "protection" is obtained if there are very well trained personnel that work in this field maintaining the competence, the expertise and the skill.

It is important to keep in mind that the subjects related to these fields require a constructive collaboration between Physics, Chemistry, Biology, Medicine that are only different chapters of the unique great book of the "Life Science". Only with education and training the situation is likely to be stem.

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REFERENCES

[1] Slovic P., *Science*, **236** (1987) 280.
[2] Slovic P., *Bull. Atom. Sci.*, **68** (2012) 67.
[3] Groppi F., Bazzocchi A., Manenti S., Gini L. and Bonardi M., *AIP Conf. Proc.*, **1164** (2009) 93.
[4] Catalano R., Immè G., Mangano G., Morelli D. and Rosselli Tazzer A., *Radiat. Meas.*, **47** (2012) 105.

[5] Immè G., Catalano R., Mangano G. and Morelli D., *J. Radioanal. Nucl. Chem.*, **299** (2014) 891.
[6] De Cicco F., Balzano E., Limata B.N., Masullo M.R., Quarto M., Roca V., Sabbarese C. and Pugliese M., *Phys. Educ.*, **52** (2017) 065003.
[7] World Health Organization, *WHO-Handbook on Indoor Radon, a Public Health Perspective* (WHO) 2009.
[8] Millar R., Klassen K. and Eijkelhof H., *Phys. Educ.*, **25** (1990) 338.
[9] Bochicchio F., Campos-Venuti G., Piermattei S., Nuccetelli C., Risica S., Tommasino L., Torri G., Magnoni M., Agnesod G., Sgorbati G., Bonomi M., Minach L., Trotti F., Malisan M.R., Maggiolo S., Gaidolfi L., Giannardi C., Rongoni A., Lombardi M., Cherubini G., D'Ostilio S., Cristofaro C., Pugliese M., Martucci V., Crispino A., Cuzzocrea P., Sansone Santamaria A. and Cappai M., *Radiat. Meas.*, **40** (2005) 686.
[10] Bochiccho F., *Radiat. Prot. Dosim.*, **160** (2014) 8.