

**EU best practices-based education in Radiation
Protection and Nuclear Safety Culture for the Belarusian
Academia/ RADIUM**

Staff Training Nuclear Physics and Radiochemistry

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1. Introduction

The topics of the Staff Training were Nuclear Physics and Radiochemistry along with connected issues in Radiation protection.

When major obstacles for the Belarussian partners could be foreseen to travel to Mannheim, we decided to give an online-course instead of one in presence. This was not an easy decision as our experiences with students and professionals in our regular courses indicated difficulties in communication between participants and instructors as well as amongst each other. In addition, we were seeking for a method to replace the practical exercises in the laboratory playing a dominant role in our educational concept.

2. Educational Concept

Our didactic model consists of four steps:

- Understand theory lying behind.
- The first is achieved by lecturing combined with solving simple conceptual and calculational problems of each topic.
- Do experiments.
- When doing experiments the learners use their senses to get "hands-on experience" involving other brain structures to anchor the learning topics better.
- Analyze data.
- Data analysis reconnects the theoretical knowledge (step 1) with the data measured in step 2. One of the outcomes is the comparison of the own data with theory or results of "best" measurements leading to a discussion of the reasons for the deviation of the good agreement. This step also fosters critical thinking along with applying judgement. This step further hardens the knowledge and skills.
- Apply the new knowledge to problem cases (with or without known solutions).

When someone is able to reflect the gained knowledge and competence and to apply it to problem cases with known solutions one can analyze how it is applied to problem-solving and may go one step further to propose new solutions.

The difficult task was to show these steps to the participants and have them following these steps in selected cases with us even in their absence from our laboratories.

3. Realisation

Monday morning started with an introduction of all the participants. It became obvious that a large fraction of the Participants from Belarus had inappropriate active language skills to be able to get involved actively. This applied - in particular - to the discussion planned on the various topics. Hence, we needed to develop a novel methodology to get the partners actively involved.



A typical workday therefore started with one or more introductory lectures. In fact, when we discussed topics of radiation safety in addition to those of Nuclear Physics and Radiochemistry more than one lecture unit was given. In the beginning of the week the focus was on Detection and Measurement of Ionizing Radiations and gradually was shifted towards Radiochemistry topics. The schedule of the Staff Training is added as Annex 1 to this document.

The experimental parts consisted of

- movies in which each experiment was explained and carefully conducted;
- experiments shown in real-time broadcast;
- experiments explained as they were similar to the shown ones.

Typical data were presented and the typical data analysis illustrated in live broadcast. This frequently involved the use of a spreadsheet program for calculation and preparing typical graphs of the analyzed data. Additional topics as calculation of uncertainties, comparison with literature data or the theoretical description etc. were done and discussed.

In the last step, problem cases were discussed in which the competences developed in the experiments and their analyses were applied.

The topics covered in the Nuclear Physics part were: Fundamental working principles of detectors for ionizing radiation, radiation shielding, the inverse square-distance law, spectrometry of alpha-, beta- and gamma-emitters, in the Radiochemistry part Neutron Activation Analysis, Decontamination, Carriers, Tracers, the use of Radionuclide generators, and the application of radiochemical separation techniques as well as of radioanalytical techniques.

The first experiments in Nuclear Physics are the basis of Radiation Protection. Hence, radiation safety culture was developed along with the topical subjects and addressed in the special context of each module.

As discussion was influenced greatly by the online format as well as by missing language skills, we were able to stimulate the partners giving their comments as written contribution in the chat as well as by mail. ("Unfortunately, my poor knowledge of spoken English did not allow me to be a more active participant in the training. I will present a more meaningful review in writing.")

In the middle of the course there was a half day contribution by Dr. Felix Sassen from Westinghouse Electric Germany GmbH on Reactor Safety in all phases of its lifetime and possible contributions of his company to safe operations. The presentations were well received and triggered many topical questions.

4. Reflection and Consequences

All participants got an insight in our teaching methods involving not only teaching theory but doing experiments reflecting it and opening the mind to apply the gained knowledge to develop and provide solutions. This teaching method was well understood (Responses from the Belarussian partners are quotes from the online chat.)



"Thank you! This was quite helpful to me. It was especially important to see the process of taking real measurements." "Thanks for your great work for us. All information is interesting, useful and relevant." "In my opinion, the only drawback of the training is the online format. Thank you!" "Thank you very much! Everything is very interesting and useful and detailed!" "I am impressed by the successful balance of theory and practice, as much as possible in an online format. Thank you very much for the information provided." Some of the partners are using a similar methodology, already: "We do the same, but we have not such equipments unfortunately" There were also many specific questions on the usage of certain types of detectors, special details of their operation, sample preparation etc. where we took care to answer as soon as possible. With increasing duration of the training the participants became less shy and asked many questions on details and application to their own field of research. By doing so, we were able "creating a creative atmosphere for discussion and questions" Several contributions addressed the "nice" and "modern" equipment of our laboratories as opposed to their own ones ("We only have personal dosimeters which are 30 years old"). I am sure that there will be great improvements by the new equipment ordered in the framework of this RADIUM project. ("with the purchase of new equipment our opportunities will expand"). There was great interest in receiving copies of the movies on the different experiments. As they require large memory space we prepare to send them to the partners on memory keys. There were request to use our lecture materials and – most of all- the movies on the experiments.

5. Conclusion

To conclude: the partners were highly satisfied with the quality and selection of the material prepared. They considered the training to be given on a high level by highly competent instructors. The methods and contents will be used to set up own courses if they are not yet existing. Nevertheless, as working with radioactive materials, in particular open radioactive materials is based on licenses given, some partners feel it to be difficult to receive such licenses.

For several participants the field of radiochemistry was completely new and they felt that their horizon had been broadened.

It was also claimed that they had learned new techniques to present the materials and structure their own lectures.

There was a high degree of satisfaction for the Staff Training course. Many of the partners wish the support and cooperation to continue even after the end of the RADIUM project.

Details can be seen in the contributions in the chat section (sorted by topic).

Annex I: Schedule of the Staff Training

Table 1: Schedule of the Staff Training

Time CET	Monday July 12	Tuesday July 13	Wednesday July 14	Thursday July 15	Friday July 16
08:30 – 10:00	Welcome Introduction of Partners Introduction to Program	Measurement of Gamma Radiation	Westinghouse: 1. Supporting Operations: a. Asset Management (LTO) b. Market Adaption (FPO) c. Risk Informed Applications for Maintenance d. Component surveillance (e.g. Vessel – EVND, ...) e. Obsolescence Management	Decontamination Open Sources: Decontamination	Radiochemistry 3 Radioanalytical Methods Titration, IDA, Solubility of PbI ₂
10:00 – 10:15	Break	Break	Break	Break	Break
10:15 – 11:45	Fundamental Measurement Methods Radiation Detection 1 Characteristic of GM Tube	Radiation Detection 2 Spectrometry SMCA Radiation Detection 3 LSC	Westinghouse 2. Supporting Licensing: a. License Renewal b. Deterministic Safety Analysis c. Probabilistic Safety Analysis.	Introduction to Radiochemistry	Radiochemistry 4 Radionuclide Generator Half-life of Pb-212 and Tl-208
11:45 – 12:30	Lunch Break	Lunch Break	Lunch Break	Lunch Break	Lunch Break
12:30 – 14:00	Radiation Properties 1 1/r ² law, Statistics	Radiation Detection 4 Alpha Spectrometry	Radiochemical Protective Techniques, RP Measurements	Radiochemistry 1 Carriers	Synthesis



14:00 – 14:15	Break	Break	Break	Break	Break
14:15 – 17:00	Radiation Properties 2 Shielding Concluding Remarks	Radiation Detection 5 HR Gammay Ray Spectrometry Concluding Remarks	Safety Instructions Neutron Activation Analysis Concluding Remarks	Radiochemistry 2 Preparation of Carrier-free Mn- 56 Concluding Remarks	Final Discussion Farewell



Annex II: Copy of the Chat Sorted by Topics

Educational

Thank you! This was quite helpful to me. It was especially important to see the process of taking real measurements

Thank you so much for your lectures

The material is presented in an accessible language, so there were no questions

I am impressed by the successful balance of theory and practice, as much as possible in an online format. Thank you very much for the information provided.

Thank you for the interesting lecture, dear professor, very informative!

Need for: Radiometry & Dosimetry, Nuclear Safety Culture And practice

Thank you for agreeing to help us!

Overall impression of the entire training very good

The training has learned them some new subjects (mainly radiochemistry for the physicists, also basic knowledge for some others), broadened their horizons • learned new techniques for presenting, structuring their lectures

It was asked to be able to use our materials for the build up of lectures in Belarus.

HS Mannheim has proven, that also online lectures can be very interesting and diversified.

Lectures were very open, answered questions, shared a lot of experiences and the atmosphere created by them was a nice environment to learn

The patience of the lecturer was thanked

Experimental

We do the same, but we have not such equipments unfortunately

I am also of the view of the need to upload into the common folder all videos

Are there liquid scintillators for registering protons, neutrons and ions?

Is it possible to prepare several samples simultaneously or one by one?

Do you take into account the angular pattern of the radiation source? I mean the non-isotropic nature of the radiation

How often is it necessary to calibrate the spectrometer (start of work, separate experiment, series of experiments, etc.)?

Do you participate in the interlaboratory calibrations? National, IAEA?

I am impressed by the table with edges for preventing liquid spills) and of course, other equipment. Has any accident happened with the participation of students in your lab?

Is there a regulation on wearing an individual dosimeter in university laboratories? In the video (yesterday), a colleague has a dosimeter. You don't have it

Organizational question. Do the students distribute their tasks without problems or you do it? If 3 students are in group what is the task for the third one?



How to create sources with a small amount of a radionuclide with a high specific activity, for example ^{210}Po (the mass of a nuclide is about μg)?

How you do regenerate the exchanger if it is needed?

Are there methods (instruments) to monitor reactions with nuclides in a dynamic mode?

Is there such a need?

Do you perform anhydrous titration?

Are all of your lab experiments evaluated equally? Any difficulty factor: thi lab "weghts" more, another less?

Do you have an automatic titrator?

How many students can be in the laboratory at the same time?

Do you confirm the titration data by radio analysis? Are nuclides used in reactions?

In the regard of some students are afraid to work with the radioactivity have your students to perform all experiments within your Radiochemistry course or just e.g. 4 from 5?

The videos made were very clear and good explained

The Experiments shown in the training were very interesting, but some experiments will not be able to be done by Belarusian Universities, bcz. Laboratories do not have the licences and sometimes not the money to buy certain sources with needed Activities.

The lectures and practical work concerning Radiation safety and dosimetry was of great interest, and will be used in Belarus for students as well.

Online-Format

In my opinion, the only drawback of the training is the online format. Thank you!

The organization of the course was very good

Most people prefer offline learning;

I like the combination of theoretical material with practical examples of calculations and laboratory works;

Issues Related to experiments and equipment

What does the gamma radiation spectrum of the background atmospheric look like?

What is the lifetime of semiconductor detectors for low and high doses of accumulation of radiation defects?

If there is a choice what do you prefer dozimeter and radiometer or dozimeter-radiometer two in one?

When irradiated with thermal neutrons, some elements of the material are transmuted (transmutation doping). Does this process affect neutron activation analysis measurements?

Different radioisotopes have different half-lives. How is it taken into account in the NAA methodology?

Are there combination detectors in the NAA technique to improve isotope detection?

What is the main active component of the paste for skin decontamination? Is it commercially available?



Does induced radioactivity play a significant role?

The walls in the NAA laboratory are unpainted. Is this done specifically for the decontamination procedure?

Are there surface pretreatment reagents to improve decontamination?

General

Thanks for your great work for us. All information is interesting, useful and relevant.

Thank you very much! Everything is very interesting and useful and detailed!

Thank you very much, it was very nice

I would like to thanks, all is interesting

спасибо

Thank you for your great and very useful work for us.

Thanks for the training. Thanks for the informative video.

Remark. Who does not work does not make mistakes

Thank you Professor Ulrich and your colleagues for an interesting and useful course.

I have a very good impression of your lectures.

Unfortunately, my poor knowledge of spoken English did not allow me to be a more active participant in the training.

I will present a more meaningful review in writing.

Dear colleagues and friends.

The internship program was rich and varied.

The following questions were helpful to me: 1. Spectrometry and radiation detection; 2. Neutron activation analysis; 3. New for me - the basics of radiochemistry. Of course, everything is based on nuclear physics, molecular physics, but for me this is a new look at the control of the transformation of substances in chemical reactions. I am glad that I was able to ask questions and received full answers. With your permission, I would like to use this information to create my master's course Nuclear energy: towards sustainable development. I hope for help, the opportunity to consult. Thanks to Prof. Dr. U. W. Scherer, D. Krupp, Dr. L. Lens, F. Sassen Thanks for the training)))

Many thanks for the interesting training. Particularly useful for me is a detailed analysis of the laboratory practice. Our approach to laboratory work is in many ways similar, but your experience will definitely be useful not only in the "Radiation Safety" course, but also in the "General Physics" course. Thank you!

Thank you Professor Ulrich Scherer and your colleagues for an interesting and useful course.

I have a very good impression of your lectures.

Unfortunately, my poor knowledge of spoken English did not allow me to be a more active participant in the training.

I will present a more meaningful review in writing.

ужен новый тренинг по открыванию бутылок (радиоактивных))))))

Need new bottle opening training (radioactive))))))



Everybody would like to cooperate with HS
Mannheim also after the training and the Radium program has finished

Research related issues

In the study of the strength properties of polymers, we use ^{60}Co gamma-ray irradiation. Do you have data on the effect of gamma-ray irradiation on the properties of polymers (strength, fragility, adhesion of polymer films)? What literature can you recommend for studying this issue?

Do you conduct research on radioactive contamination of food or soil?

Do you have experience in preparing samples? thank you, this is relevant for Belarus.

Presentation of industry partner

Does the company participate in the creation of the concept of sustainable development for partner countries

Name the leading manufacturers of materials involved in the creation of devices

Does the company participate in the decontamination (disposal) of nuclear products
Felix, if it's not a secret, what are the main software packages used to conduct Finite Element Analyzes with Hydrodynamic Coupling

How do you collaborate with the National Authorities in Europe like Ibedrola, STUK, CEA? Common recommendations, etc.? Is there any conflict of interests?

Does the company participate in the development of radiopharmaceuticals?

How the company solved its tasks in the total lockdown time? What activities did you focus on mostly?

What kind of specialists does the company currently need? Is there a shortage of specialists?

Thanks for the active participation and engaging discussions.

- Very interesting presentations
- Felix very open and helpful

Closing remarks Friday, at the end of the course:

Questions:

Can we give advice for online courses for students in Belarus?

- In the time, that students were not allowed to be for practical works in the universities in Belarus, also there videos were made and shown to the students

Can we give a curriculum as example mandatory to give lectures to students here in our university?

- We will uploade a module description of our radiochemistry course

Is it possible to get a certificate for the training?

- Yes we will provide one.

Review Westinghouse:

- Very interesting presentations



- Felix very open and helpful

Review HS Mannheim:

- Overall impression of the entire training very good
- The training has learned them some new subjects (mainly radiochemistry for the physicists, also basic knowledge for some others), broadened their horizons • learned new techniques for presenting, structuring their lectures
- It was asked to be able to use our materials for the build up of lectures in Belarus.
- HS Mannheim has proven, that also online lectures can be very interesting and diversified.
- Lectures were very open, answered questions, shared a lot of experiences and the atmosphere created by them was a nice environment to learn
- The patience of the lecturer was thanked
- The organization of the course was very good
- The videos made were very clear and good explained
- Everybody would like to cooperate with HS Mannheim also after the training and the Radium program has finished
- The Experiments shown in the training were very interesting, but some experiments will not be able to be done by Belarusian Universities, bcz. Laboratories do not have the licences and sometimes not the money to buy certain sources with needed Activities.
- The lectures and practical work concerning Radiation safety and dosimetry was of great interest, and will be used in Belarus for students as well.
- It was asked to please give a certificate for the training

Annex III: Copies of the sections „Strengths and Weaknesses of the Training“ and “Comments“ of the daily QC questionnaire.

Monday:

S&W:

1. Online format of training 2. Academic quality of teaching staff; I am very pleased with the organization of the training. It's nice that not only the theory, but also the video of the laboratory experiments were presented; Strengths of the training: Good preparation of training materials and lecturers professionalism; Very interesting and useful, thank you; There were no weaknesses. The training was at a high level, very competent teachers. The presentations and videos were very interesting and informative; I am very pleased with the organization of the training. It's nice that not only the theory, but also the video of the laboratory experiments were presented; Organization of the training at a high level. I really liked the presence of experiments and their analysis; Strengths - high expertise of the lecturers and high academic quality of the material, very well becoming videos of the laboratory measurements and detailed explanation of the processing of the results. Weaknesses - were not noticed; No

Comments:

Most people prefer offline learning; I like the combination of theoretical material with practical examples of calculations and laboratory works; Thank you for the first day of the training. It's a pleasure to work with you! Thank you very much for the opportunity to participate in the training! May be the discussion will be more active in the following days. Belarusian participants were a little bit shy to comment.)

Tuesday:

S&W:

No weaknesses; In my opinion strengths of the training is the use of modern equipments and the style of information presentation; There are no weaknesses. Very informative



lectures and experimental works.; I liked the live

demonstration of the laboratory experiments in real time.; Very interesting and useful, thank you; Strengths of the training: Deep presentation of the declared topics of the lectures. Creating a creative atmosphere for discussion and questions;

Comments:

The combination of videos and real-time measurements was great.; I was impressed by the detection methods; The information is very helpful. Thank you for the video submitted by the behavior of experiments and measurements.; Thank you for your prompt answers to questions; Part of materials I remember from courses of Nuclear Physics and Radiation Safety;

Wednesday:

S&W:

No weaknesses; I am impressed by the table with edges for preventing liquid spills and of course, other equipment; Very nice explanations, nice English (to hear is equal to take courses :)); Additional strength is attraction of the highly qualified specialists from the industry. The strengths is also easy but highly professional atmosphere.; It was very nice to talk with a representative of the Westinghouse Electric Company. There were no weaknesses of the training.; It is very informative to communicate with the employees of such a production as Westinghouse.; I like practical information on shielding, personal and laboratory protection, dosimetric measurement techniques and detecting contamination. I hope it will be especially valuable for developed courses at Francisk Skorina Gomel State University. Also thanks for the warm atmosphere and communication after the main part.; Strength: detailed and complete information on working with radiation detection equipment.;It is very interesting; Lectures are linked with practical examples, video demonstrations.

Comments:

Interesting information from Westinghouse, impressive video about Neutron Activation Analysis, exciting on-line social event; At our university, we conduct laboratory classes in the same way as you told. They also first study the theoretical part of the work, then disassemble the procedure for performing experiments and get acquainted with the structure of the experimental setup. After completing the experiments, students analyze the data obtained and draw up a report with the formulated conclusions on the work done. After all this, they submit a report for verification and we talk with them.; Your various devices are very impressive; Many thanks for the organization!; Many thanks to



Felix Sassen for providing information on such modern equipment and measurement methods.; thanks; I would like to get access to video materials.

Thursday:

S&W:

No weaknesses; Strengths: high professionalism of the lecturers and high quality of the material. ; The positive side is pleasant communication with professors, a high level of training of lecturers.; There are no weaknesses. Strengths - full immersion in the laboratory workshop, very informative lectures, responsive and professional lecturers.; Strengths of the training: Detailed explanation of the material supported by real situations; Strength: Shows in detail how to make learning the safest for yourself and your students.

Comments:

Great presentations and movies about decontamination and preparation of sources. ; Thank you for the knowledge gained and for the presented practical videos.;It is a pity that I did not manage to visit your laboratories in person. I was very impressed by the equipment you are working with; Thank you for a very interesting training!;

Friday:

S&W:

No weaknesses; There are no weaknesses. One of the strengths is a very pleasant atmosphere, easy communication with all participants of the training;

Comments:

Great presentations and movies about radiometric titration and solubility experiments, very friendly atmosphere at the farewell!; THE GREATEST WORK!!!; We have very little equipment for radiation safety, nuclear physics. Only individual dosimeters that are 30 years old. It was very interesting for us to look at your equipment, how you conduct laboratory work and analyze the results. It is a pity that we did not get to come to you. We have the same methodology for conducting laboratory work for our students, we also remind the theory, try out conclusions on the work, set deadlines for completion. And with the purchase of new equipment, our opportunities will expand.; Thanks for the experience we got.