General project information

Project title	**Rapid assessment of internal exposure risks**
Project duration (months)	48
Call topic addressed	4. Development of techniques and methods to go beyond effective dose in case of internal exposures following a nuclear or radiological emergency.
Expected project start date (not later than 1 Dec 2025)	1 October 2025
PIANOFORTE partner leading the project and status (BEN or AE), (and hiring the PhD student which will be financed)	National Radiation Protection Institute, SÚRO, Prague, Czech Republic - BEN
Academic institution (university where the PhD will be defended)	Czech Technical University in Prague, Czech Republic

Project leader

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PhD student principal supervisor (optional if other than the project leader)

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Role in the project	PhD thesis supervisor, Expert in detector technologies

PhD student co-supervisor (optional)

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Role in the project	Expert in internal contamination measurements

1. Project summary (abstract)

In response to a severe radiological emergency, it is crucial to triage a potentially large number of individuals with external as well as internal radionuclide contamination. The primary goal of this project is to develop tools for the rapid assessment of absorbed doses from internal exposures. This includes creating methodologies for the automatic identification of radionuclides using a robotic system equipped with various detectors tailored to different exposure scenarios, including wounds. Additionally, a parallel approach will involve determining radionuclides directly from blood samples. Pixel silicon detectors and CdTe detectors will be evaluated for their ability to differentiate between radiation types.
This information will be particularly valuable for dose assessment in cases involving alpha particle emitters. The project will explore the possibility of determining radionuclide activities and correlate them with corresponding organ doses. Capacity exercises will be conducted, and appropriate protective actions, such as medical treatment or long-term follow-up, will be recommended, taking into account medical, legal, social, economic, and psychological factors.

2. Project description

Project title “Rapid assessment of internal exposure risks” refers to Pianoforte consortium objective “The improvement of anticipation capacities and resilience in nuclear or radiological crisis situations and post-accident management“.

2.1. State-of-the-art and preliminary results *(Excellence)*

Current methods and tools for the evaluation of the committed effective dose from an internal contamination cover mainly occupational, accidental, and mass scale exposure leading to risk of stochastic health effects. Events and threats in the past (nuclear and industrial accidents, exposure to lost radiation source, nuclear terrorism against an individual and population) require the development of mass scale response methods and health effect evaluation. Procedures within the response are described in separate works as well as in comprehensive projects (e.g. TIARA project and TMT Hanbook [1,2]). Traditional methods are described also for monitoring of workers in case of incident at the workplace [3,4]).

Less attention has been paid to adapting of measurement techniques and evaluation methods for extraordinary exposures. As a standard, laboratories are equipped for routine measurements expecting low doses from internal contamination within their monitoring programmes. Modifications or extensions to measurement instruments are not always developed for extraordinary urgent measurements. Also improvised methods and instruments should be prepared for rare but serious events. Such ready-to-use instruments and methods can be missing under the pressure of the emergency situation.

Also schemes are not elaborated for procedure when high the dose limit for stochastic effects is exceeded significantly. In vivo or in vitro techniques for rapid measurement of hardly-to-detect radionuclides are not always at hand.

This state-of-the-art has been considered in a research conducted in the past and present in SÚRO (National Radiation Protection Institute), Prague, CZ. Results and publications prove feasibility and relevance of new or modified methods for extraordinary urgent measurements of high radionuclide intakes:

- bremsstrahlung counting in vivo [5]
- pixel and CdTe detectors counting for evaluation of surface and wound contamination by alpha and beta emitting radionuclides [6],
- use of robotics for help during laborious or precise measurements in vivo [7].

2.2 Research hypothesis and strategy *(Excellence)*

Inovative ideas: Pixel detectors (TimePix series) are unique in displaying contamination by alpha and beta particles together with its intensity and spatial distribution of the contamination. The detectors have been tested for the wound counting that sets several challenges in case of multiple wounds.

Laborous and time consuming precise detector positioning during body or wound scannig can be facilited with the help of a robotic arm that is able to hold small and light detectors. The use of robotics in in vivo mesurements is unique and the whole body counter in SÚRO is equipped with such a robotic arm. Man-power is saved if precise manual positioning of detectors is required repeatedly. This method is especially suitable for alpha and beta particle emitting contamination on the body surface allowing to distunguish surface contamination from wound contamination. For internal contamination by pure beta emitting radionuclides (like ^{90}Sr), traditional whole body counting techique using gamma-ray detectors can be adapted and calibrated to quantify the radionuclide content in the body by counting the Bremsstrahlung radiation emitted after beta transformation in body tissues.

Decision-making charts or schemes exist for measurement of internal contamination in the frame of occupational exposure. Such schemes for serious internal contamination when deterministic health effects

are likely would facilitate decisions made under time pressure. Making proper decisions about measurement instruments, next steps in measurement strategy, not omitting somethig important, doing good estimates, etc. are the main motivation for preparation of emergency instruments and techniques.

2.3 Scientific objectives *(Excellence)*

Scientific objectives consist in the solution of following subtasks:

1) explore and determine most suitable use of new detectors in the in vivo counting, based on their theoretical properties or their use elsewhere, or propose non-traditional use of standard devices in internal contamination laboratory,
2) explore the use of above detectors with robotics device to measure effectively and save the physical effort of dosimetrist,
3) explore the use of current computational phantoms of an adult and child in evaluation of the risk of severe health effects,
4) explore and propose expansion of developed methods to mass scale use and evaluation of the health risk among large population affected and implementation in decision-making scheme.

2.4 Methods *(Excellence)*

Experimental work consisting of detector testing and calibrating will be the main portion of the work. Pixel silicon and CdTe detectors will be applied for automatic identification of surface contamination sites using a robotic system. HPGe detector will be tested and calibrated for Bremsstrahlung counting of internally deposited pure beta radionuclides. Mathematical modelling of detectors and human body will form the theoretical supportive part of the effort to describe novel measurement techniques. Parallel consideration will be carried out to incorporate the novel methods to decision-making schemes for the assessment of seriousness of the internal contamination.

For the work, entire infrastructure of the whole-body counter facility in SÚRO will be available together with the detectors, codes, and the robotic arm.

2.5 Feasibility/risk analysis/risk

Potential risk of the study lies in so far not tested new application of pixel detectors for identification of radionuclides in wounds or in vitro samples (blood samples). Good condition and perfect functionality of the experimental detectors and robotics is required for success of the work. Robust material background of the institutes involved in supervising the work should mitigate possible problems.

2.6 Time schedule *(Efficiency of Implementation)*

The work will be spread over four years.

From the very beginning a plan of experimental works will be made for the first two years with the aim to expand the scope of experiments based on results received within an initial period. Simultaneously, study of emergency measurement strategies, sources of knowledge will be carried out in order to bring inputs and modifications for the direction of the experimental works. Final two years will be devoted to the synthesis of knowledge gained in order to formulate consistent system emergency measurement of internal contamination containing novelty methods and procedures.

2.7 Impact and relevance to PIANOFORTE objectives and call topic *(Impact)*

The ambition of the project is to provide solutions for screening and examination in internal contamination emergency and thus to improve radiological protection of the public and enhance capabilities of laboratories

that identify themselves with the necessity to operate emergency techniques and tools for the assessment of risk of severe health effects after intake of radionuclides.
Proposed topic of the doctoral study is directly related to the Pianoforte goal of the development of techniques and methods to go beyond effective dose in case of internal exposures following a nuclear or radiological emergency.
All results will be disseminated to the radiation protection community by means of conference presentations (e.g. European Radiation Protection Week, Days of Radiation Protection, EURADOS and PIANOFORTE meetings) and scientific papers in relevant impacted journals (e.g. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment; Radiation Measurements; Radiation Protection Dosimetry).

2.8 References

[1] Menétrier, F., et al: Tiara: Treatment Initiatives after Radiological Accidents. Radiation Protection Dosimetry (2007), Vol. 127, No. 1–4, pp. 444–448, doi:10.1093/rpd/ncm298

[2] TMT Handbook. Triage, Monitoring and Treatment of people expose to ionizing radiation following a malevolent act. SCK-CEN 2009.

[3] EPR-INTERNAL CONTAMINATION 2018: Medical Management of Persons Internally Contaminated with Radionuclides in a Nuclear or Radiological Emergency. IAEA, VIENNA, 2018.

[4] Castellani C.M., et al: IDEAS Guidelines for the Estimation of Committed Doses from Incorporation Monitoring Data. EURADOS Report 2013-01. ISSN 2226-8057, ISBN 978-3-943701-03-6

[5] Fantínová, K. et al: Monte Carlo Simulation of the Bremsstrahlung Radiation for the Measurement of an Internal Contamination With Pure-Beta Emitters In Vivo. Radiation Protection Dosimetry, Volume 170, Issue 1-4, September 2016, Pages 354–358,https://doi.org/10.1093/rpd/ncv427.

[6] Measurement and interpretation of radioactive contamination in wound for the dosimetry of internal exposure. Certified method. SÚRO Praha, 2022. In the Czech language. Available at the SÚRO library.

[7] Slavíček, T., Broulím, J., Fojtík, P., Prokop, M., Rubovič, P., Apparatus for localization and dosimetry of wounds with radioactive contamination. Radiation Protection Dosimetry, 2022, 198(9–11), 693–697. DOI: 10.1093/rpd/ncac121