Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

PTB Metrological Infrastructure for the Environmental Dose Assessment

Ulf Stolzenberg

Physikalisch-Technische Bundesanstalt (PTB)
Working group 6.32: Dosimetry at Low Dose Rates
Department 6.3: Radiation Protection Dosimetry
Bundesallee 100, 38116 Braunschweig

Overview

PTB reference sites for environmental dosimetry

- **Motivation:** Provide reference measuring sites to ensure a national quality standard according to §103 StrlSchV
- Harmonization of environmental monitoring systems in Europe

- Overview of the **four reference sites** for environmental monitoring with special focus on the **underground laboratory** UDO II

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- Overview of the **four reference sites** for environmental monitoring with special focus on the **underground laboratory** UDO II

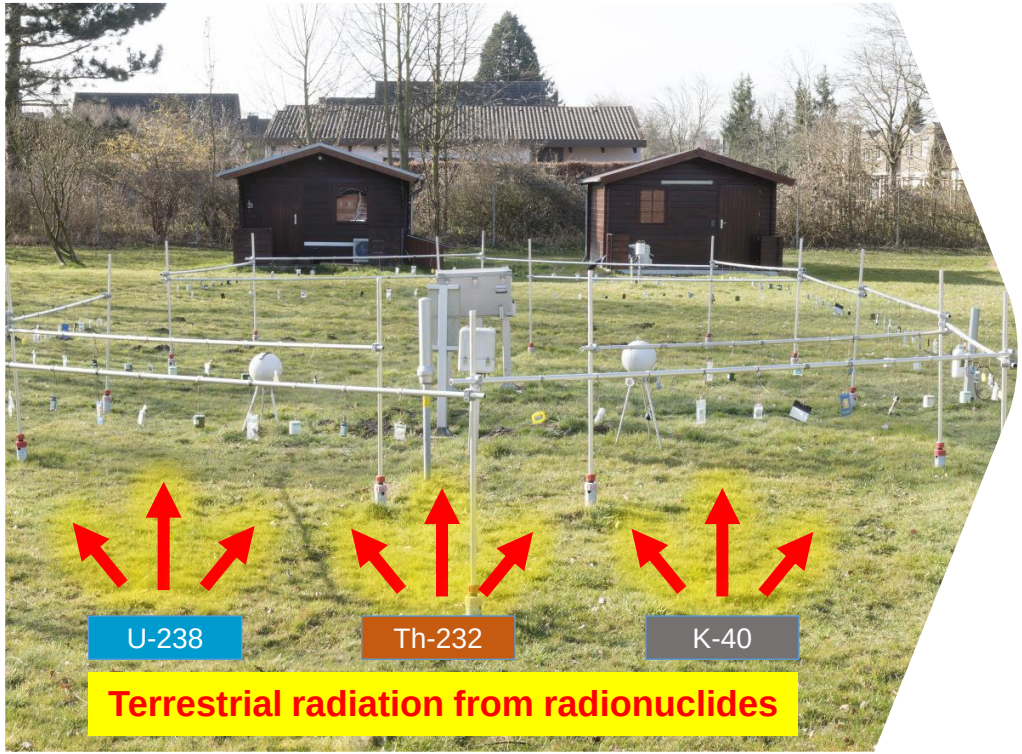
Development of new environmental dosimetry methods and technologies

- Support of radiological emergency management
- **Projects** related to **environmental dosimetry**

Environmental dosimetry at PTB

Goal: Determine and quantify (ambient dose equivalent rate $H^*(10)$) the different components from environmental and artificial ionizing radiation as accurately as possible.

Environmental dosimetry at PTB



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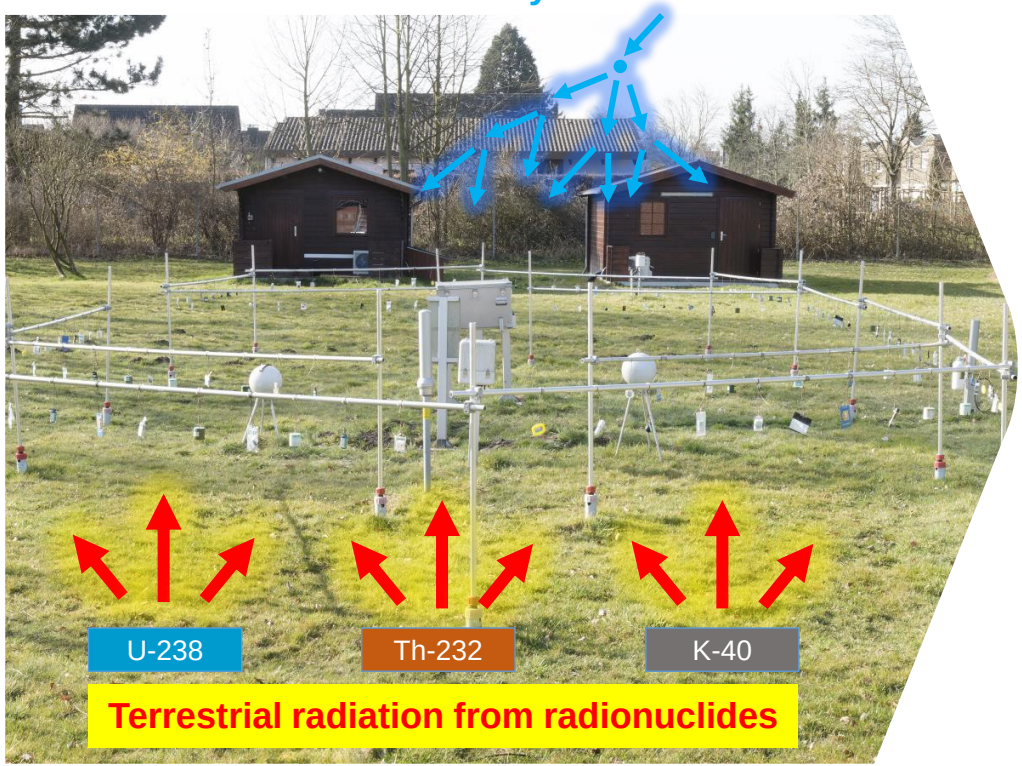

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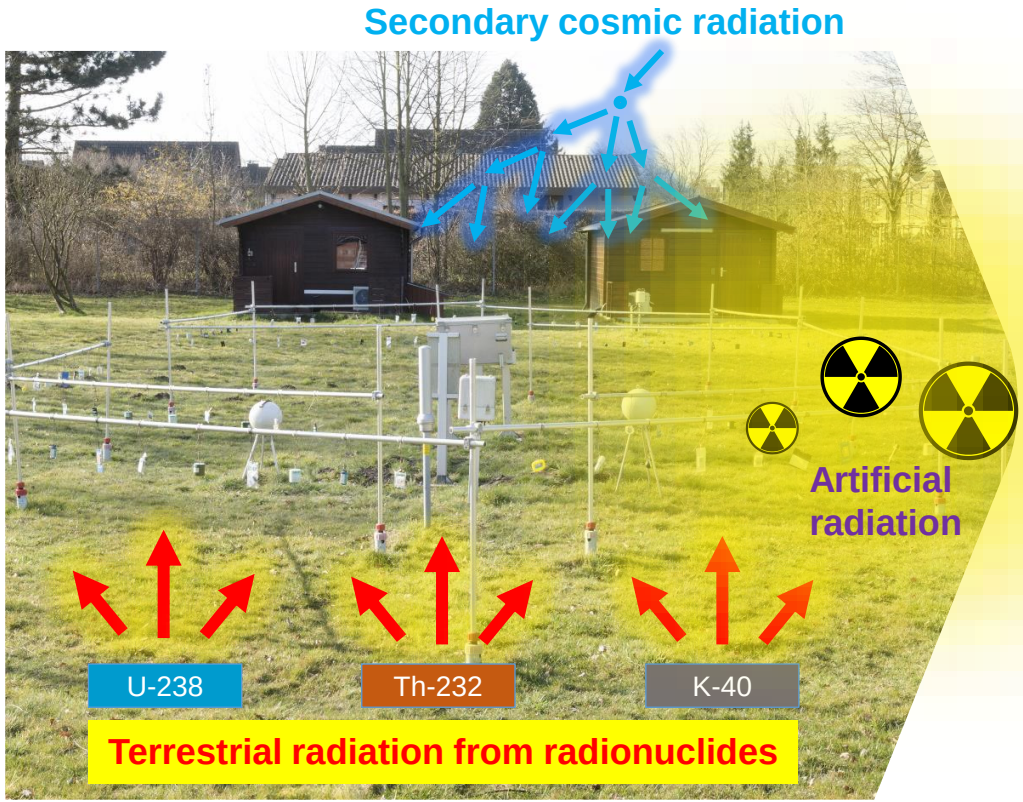

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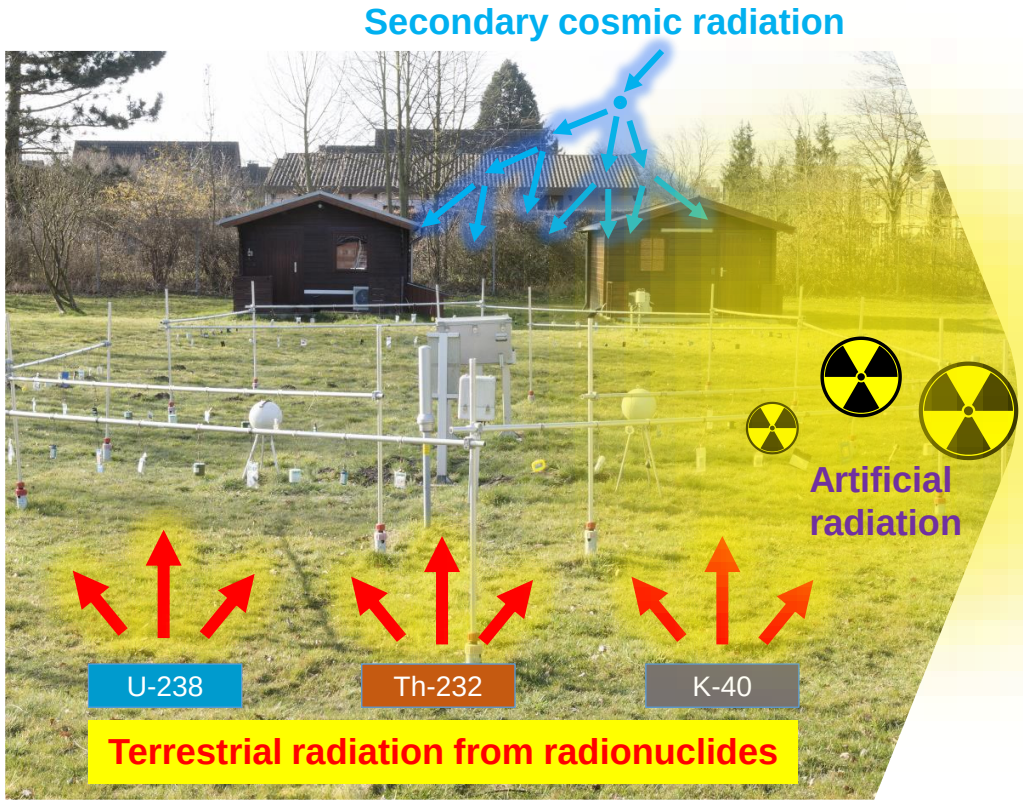

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Environmental ionizing radiation:

- Terrestrial component
- (Secondary) Cosmic component
- Artificial component

Measurements of environmental radiation

$\dot{M} = \dot{M}_0$ ⇢ Inherent background of device (**UDO II**)

$+ q_{TR}\dot{H}_{TR}$ ⇢ Terrestrial component (**UDO II**)

$+ q_{SCR}\dot{H}_{SCR}$ ⇢ Secondary cosmic component (**CORADOS**)

$+ q_{ART}\dot{H}_{ART}$ ⇢ Artificial component (if present)

$q_{TR}, q_{SCR}, q_{ART} \rightarrow$ instrument response

Determined on the reference sites of PTB

Radiological emergency protection surveillance in Europe

Characterization of the response of monitoring devices with respect to different radiation fields is essential for the harmonization of radiological emergency protection in Europe (Harmonization of early-response networks).

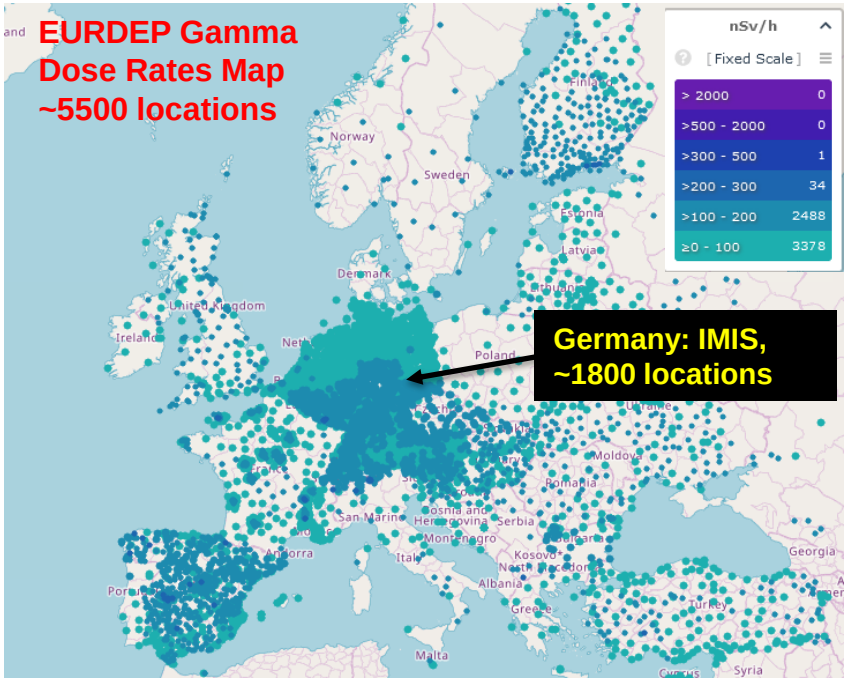
H. Dombrowski *et al.*, Radiat. Prot. Dosimetry **135**, 1-20 (2009).

H. Dombrowski *et al.*, Radiat. Prot. Dosimetry **161**, 53-57 (2014).

H. Dombrowski *et al.* 2017 JINST **12** P12024.

EURADOS Intercomparisons

(https://eurados.sckcen.be/events/intercomparisons)



EUropean Radiological Data Exchange Platform (EURDEP)
(https://remap.jrc.ec.europa.eu/Advanced.aspx)

Environment Radiation Dosimetry Site (ERADOS)

PTB reference measuring site for environmental dose assessment: ERADOS.

ERADOS is used to **investigate and monitor environmental radiation on ground**.

The radiation field is **characterized** using **several sophisticated detectors** which continuously measure terrestrial radiation caused by **radioactive nuclei in the earth's crust** and **secondary cosmic radiation**.

Ionization chambers	Reuter-Stokes, FHT Eberline, GM counters
Neutron doserate meters	LB 6411 Berthold
Spectro-dosemeters	based on CeBr3, SrI_2
Cosmic ray detectors	muon detectors

+ Devices and systems monitoring atmospheric parameters

ERADOS: Data management platform

Data Management Platform "Environmental Monitoring" is currently being commissioned for
- Data storage
- Data visualization
- Data analysis

Sensors:

radiation,

radon,

rain,

temperature,

humidity

Software on the PC's

Daily backup of CSV files to laboratory server

Backup to data center

CSV CSV CSV

File Watch-Dog. Reads data from the CSV and writes it to the SQL.

SQL

PTB - Database

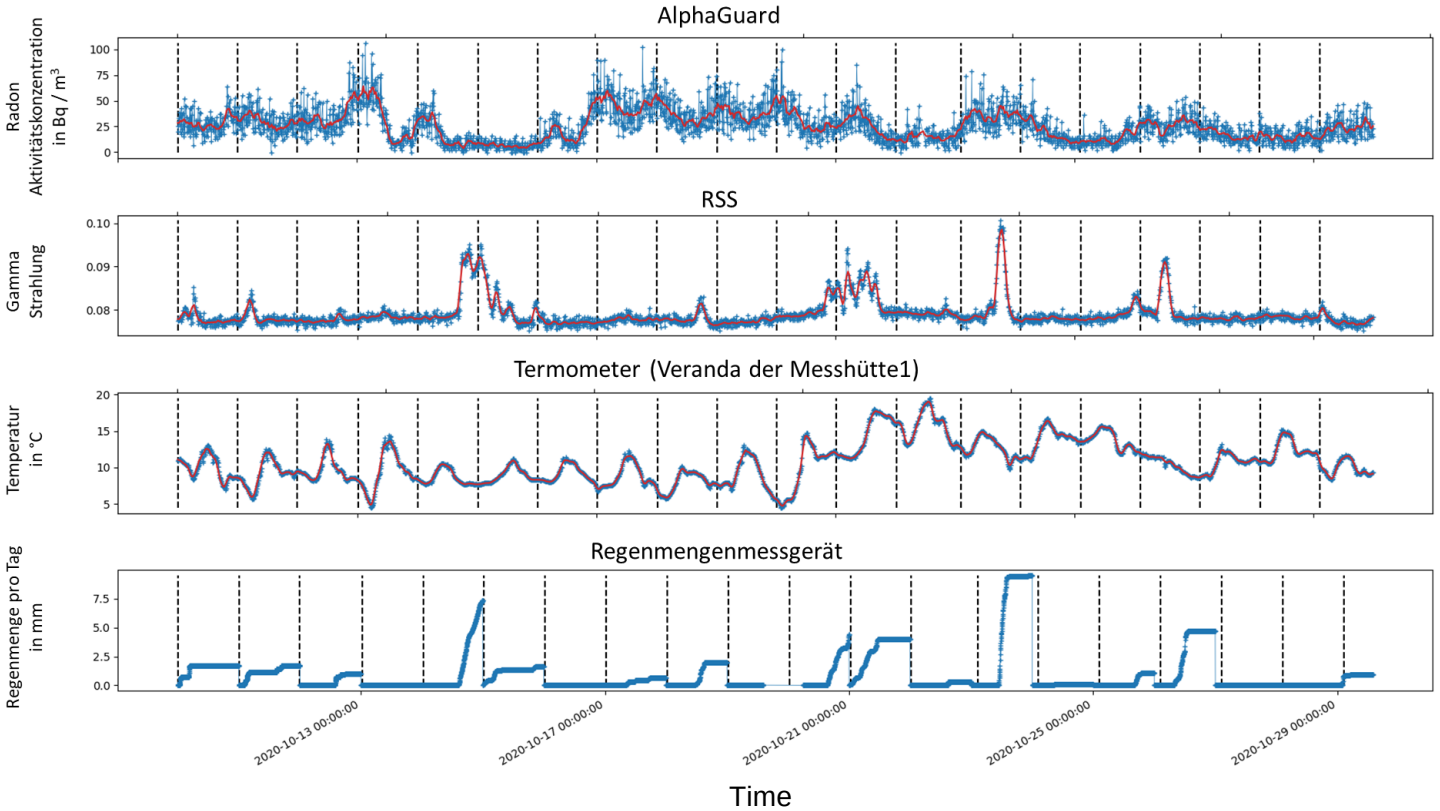
Possibility to display the data directly in the browser.

ERADOS: Data management platform

Planning: new data processing concepts (artificial intelligence approaches such as data mining)

Visualization of results:

Quick data review (identifying trends and anomalies)



The PTB Underground laboratory for DOsimetry (UDO II)

- The PTB Underground laboratory for Dosimetry (UDO II) is located in Grasleben (~ 30 mins from Braunschweig)
- Active salt mine (Braunschweig-Lüneburg rock salt mine) run by esco (Kali+Salz AG)
- Size of lab 18.5 m x 7.5 m x 3.2 m
- Mostly used for calibrations/characterizations of dosemeters from external customers and PTB devices …
- …and in the frame of type examinations of area dosemeters
- Low specific activity of pure rock salt and low activity concentration of radon in air
- Usage of well selected materials with low activities

The PTB Underground laboratory for DOsimetry (UDO II)

The PTB Underground laboratory for DOsimetry and spectrometry (UDO II) at the Braunschweig-Lüneburg rock salt mine.

UDO II is located at a depth of **430 m below the ground** and serves as a **reference facility** for calibrations at **ultralow dose rates**.

The secondary cosmic radiation intensity (exclusively, **muon intensity) is reduced by about 4 orders of magnitude** compared to ground level

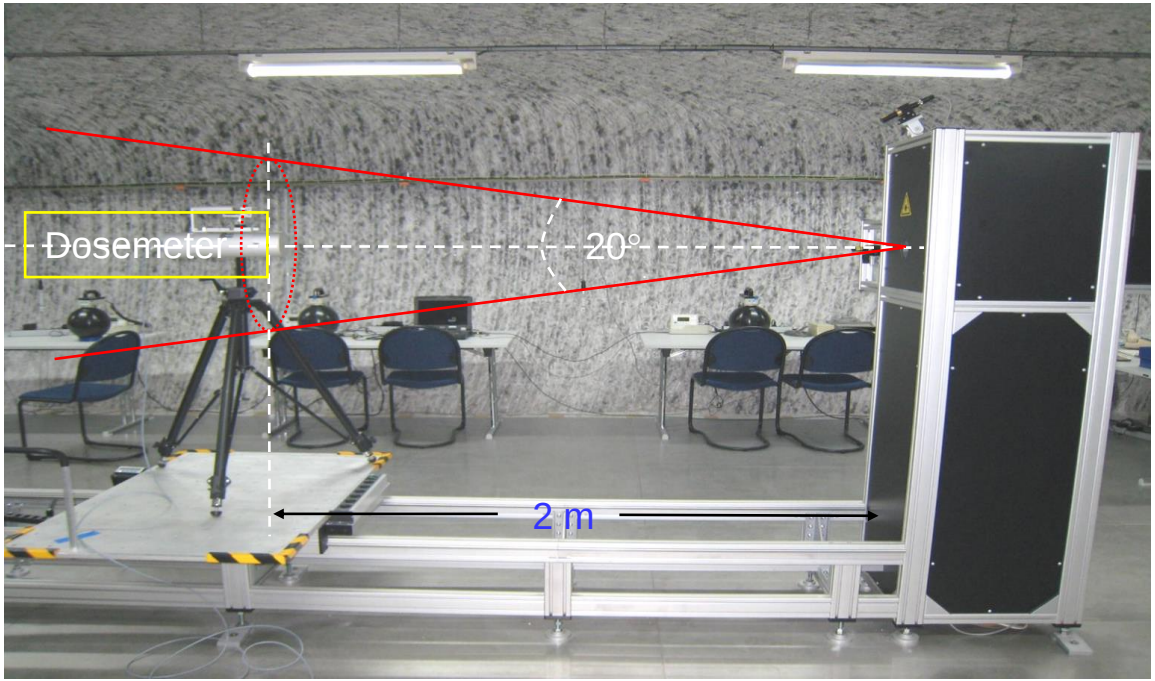
Determine $\dot{M}_0$ and q_{TR} via Ra-226

Background dose rate (1.5±0.2) nSv/h

A. Röttger and P. Kessler, Journal of Environmental Radioactivity **205** (2019) 48–54.

H. Dombrowski and S. Neumaier, Radiation Protection Dosimetry **140**, 223 (2010).

UDO II: Underground Calibration Facility



The calibration setup at UDO II.

Radiation fields generated by:

Am-241, **Cs-137**, **Co-57**, **Co-60** and **Ra-226**

with ambient dose equivalent rates **between 10 and 300 nSv/h**.

The dose rate values of this facility are traceable to the primary standards of the PTB.

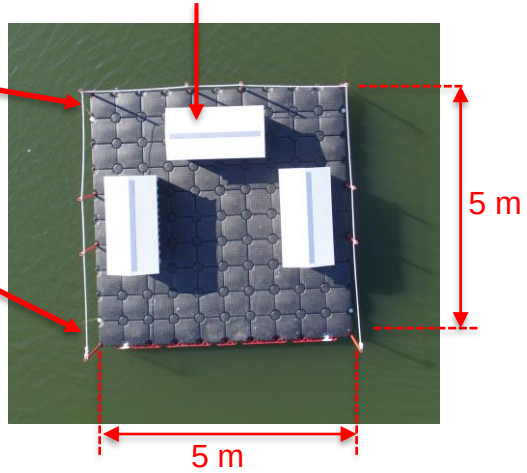
Cosmic Radiation Dosimetry Site (CORADOS)

Photograph of the floating platform installed on a lake approx. 15 km away from PTB, which serves as a measuring site for cosmic radiation.

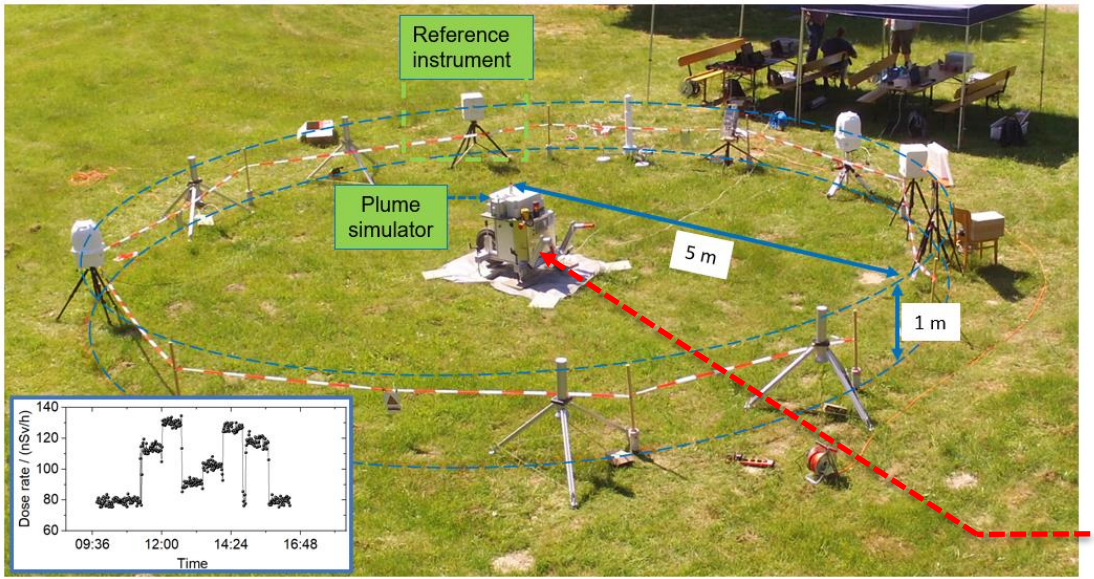
- Reference site for investigating cosmic radiation.
- Terrestrial component suppressed down to ~2 nSv/h.

Dosemeters (detectors) exposed exclusively to secondary cosmic radiation.

Plastic boxes for storing detectors



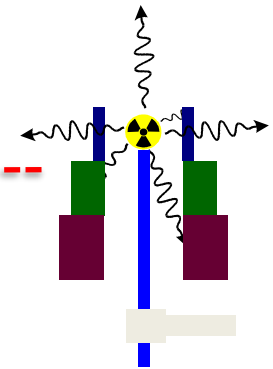
Free-field irradiation site



Simulation of a radioactive cloud for quality assurance of dosimetry monitoring systems and measurement methods. The measurement devices are installed at a radius of 5 m from the source and a height of 1 m from the ground.

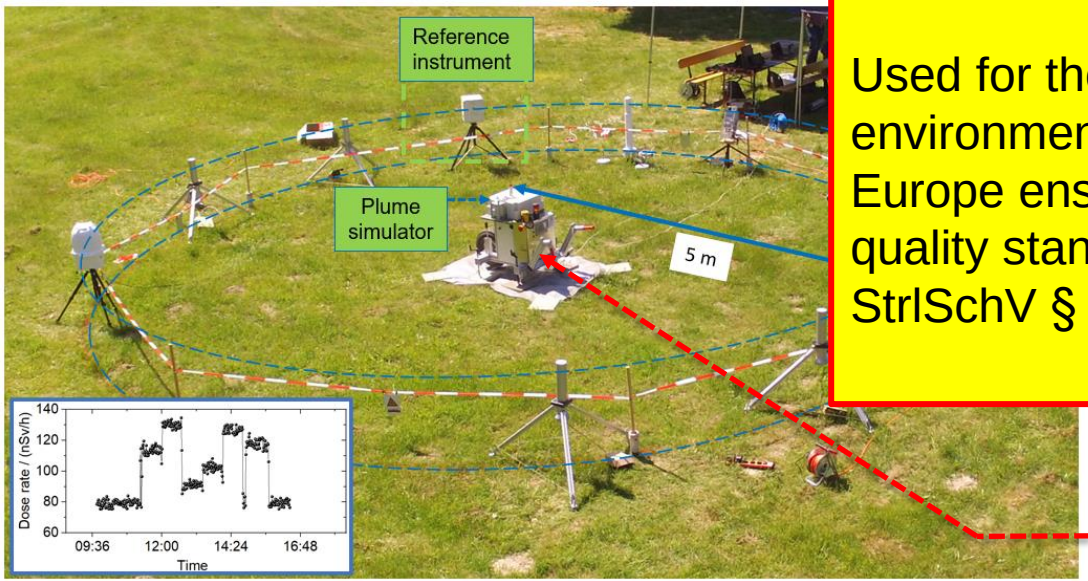
Simulation of a radiological emergency by increasing the ambient dose equivalent rate by 10-50% of normal environmental values.

Simulation device (plume simulator): Radioactive sources are moved to different positions in a lead cylinder with varying thickness.

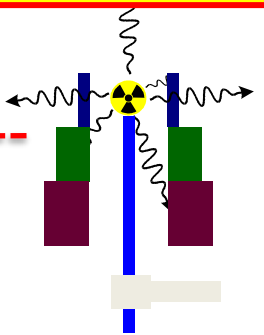


V. Morosh *et al.*, Radiation Measurements 143 (2021) 106580.

Free-field irradiation site



Used for the harmonization of environmental monitoring systems in Europe ensuring a consistent national quality standard in Germany according to StrlSchV § 103.



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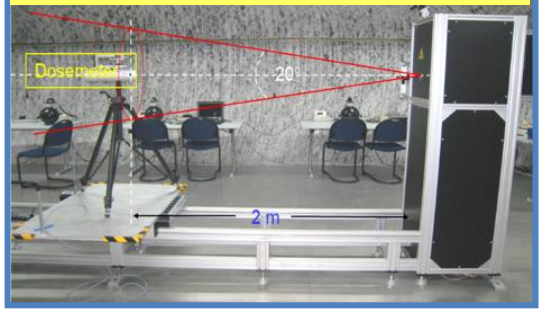
V. Morosh *et al.*, Radiation Measurements 143 (2021) 106580.

PTB reference measurement sites: Overview

Traceable to primary standards of PTB

ERADOS: reference site for secondary cosmic and terrestrial radiation

UDO II: „radiation free“ environment



CORADOS: Secondary cosmic radiation

Simulation of radioactive cloud

- They provide traceable reference values for environmental radiation.
- They ensure harmonization of early-warning monitoring systems in Europe and provide consistent national quality standard in Germany according to StrlSchV §103.
- They support of interdisciplinary projects: Investigation of correlations between ionizing radiation in the environment, climate, anthropogenic emissions and health.

Emergency preparedness: Novel Spectro-dosemeters

EMRP Projekt ENV57 **MetroERM**
(2014 – 2017)

Coordination: PTB

Goal

Support of early warning networks in case of nuclear accidents in Europe: Introduce improvements that help discerning radiological emergencies and reacting to them.

- Development of novel, improved dosimetry systems to be operated at measurement sites, which provide dosimetric and nuclide information

Partners

PTB – Physikalisch-Technische Bundesanstalt Braunschweig und Berlin
Ciemat – Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
CMI – Czech Metrology Institute
IFIN-HH
CEA List – Laboratoire National Henri Becquerel – LNE-LNHB
ENEA
NPL – National Physical Laboratory
SCK•CEN – Studiecentrum voor Kernenergie / Centre d'Etude de l'Energie Nucléaire
Jožef Stefan Institute Ljubljana, Slovenia
TENMAK – Türkiye Enerji, Nükleer ve Maden Araştırma Kurumu
Joint Research Centre JRC
Bundesamt für Strahlenschutz
IRSN – Institut de Radioprotection et de Sûreté Nucléaire

MetroERM radiological early warning

The MetroERM project is financially supported by EMRP. EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

EURAMET

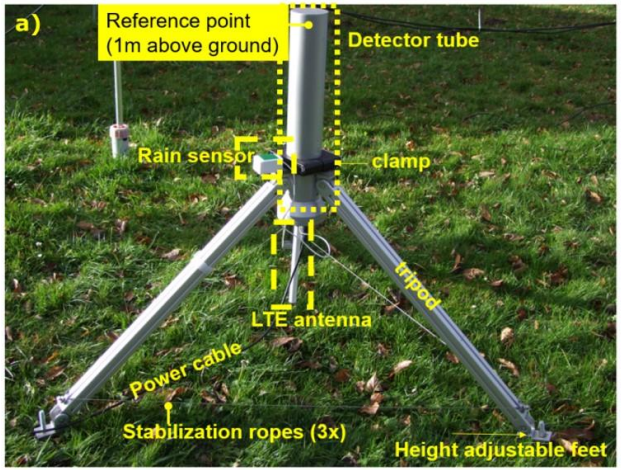
Emergency preparedness: Novel Spectro-dosemeters

Development of a **new generation of dosemeters** based on the **scintillators $LaBr_3$, $CeBr_3$** and **SrI_2** for monitoring **ionizing photon radiation in the environment**.

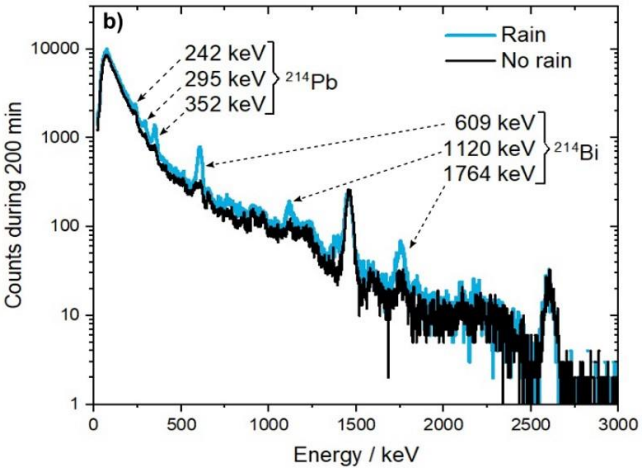
Spectroscopic information (radio nuclid vector)

+

Dosimetric informationen (Ambient dose equivalent rate)



Photograph pf a PTB developed $CeBr_3$ spektro-dosemeter system.



Measured spectra during a rain event and a dry period.

MetroERM radiological early warning

H. Dombrowski, Radiation Protection Dosimetry **160**, 269–276 (2014)
P. Kessler *et al.*, Journal of Environmental Radioactivity **187** (2018) 115–121

EURAMET

EPM Projekt 21GRD02 BIOSPHERE

BIOSPHERE

Metrology for Earth Biosphere: Cosmic Rays, Ultraviolet Radiation and Fragility of Ozone Shield

01.10.2022 – 30.09.2025

Coordination: PTB, FB 6.3

22 partners

8 NMI/DI

PTB

Budapest Főváros Kormányhivatala

IFIN-HH

Laboratoire National Henri Becquerel
LNE-LNHB

TÜBİTAK UME

Czech Metrology Institute

IMBIH

Central Office of Measures

16 externals

BIRA-IASB

DWD

RMI

Max-Planck-Institut für Kernphysik Heidelberg

Institutul National Victor Babes

NOVA School of Science & Technology

National Technical University of Athens

VJF

LZH Laser Zentrum Hannover e.V.

raymetrics lidar systems

ADVACAM Imaging the Unseen

DTU Danmarks Tekniske Universitet

Gigahertz-Optik Member of the BERGHOF GROUP

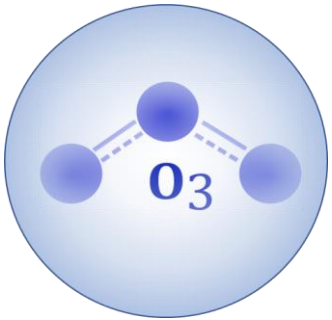
CSIC Consejo Superior de Investigaciones Científicas

Metrology for earth‘s biosphere

BIOSPHERE

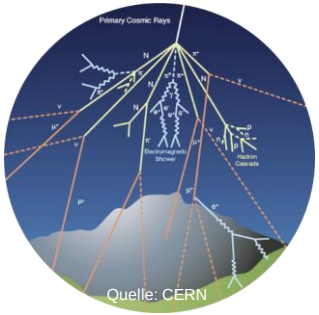
Extraterrestrial radiation in space

- Solar particle events
- Galactic cosmic rays
- Solar radiation



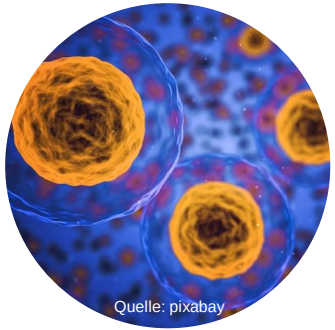
Atmospheric chemistry

- Anthropogenic activities/emissions
- Ionization in atmosphere
- Molecular dissociation
- Ozone depletion



Extraterrestrial radiation on the ground

- Muons
- Neutrons
- UVB radiation



Biology

- DNA damage
- Genomic instability
- Cell death

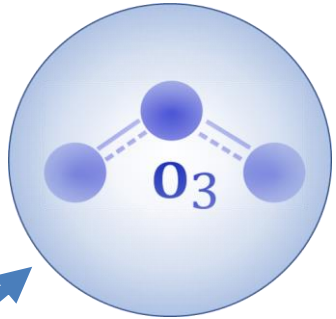
Metrology for Earth‘s biosphere

BIOSPHERE

Extraterrestrial radiation in space

- Solar particle events
- Galactic cosmic rays
- Solar radiation

New metrological methods are required to find **correlations** between them



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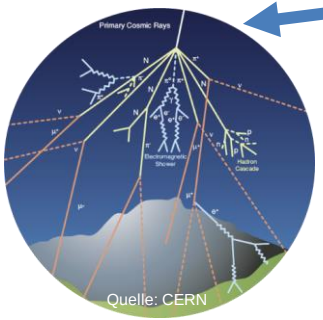

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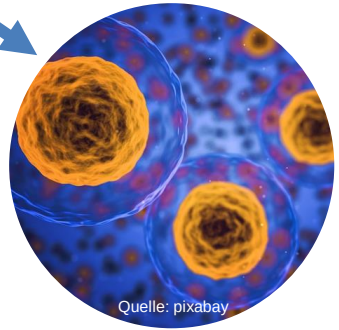

Biology

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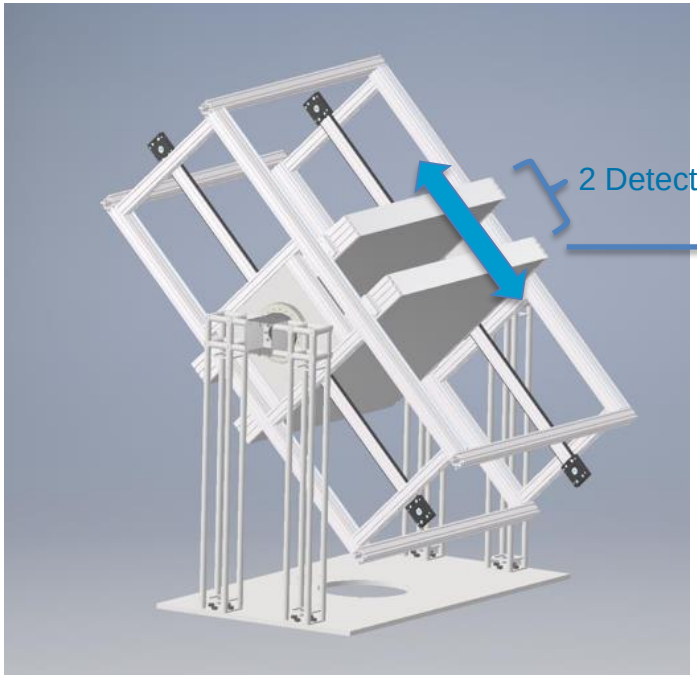
Novel muon detector

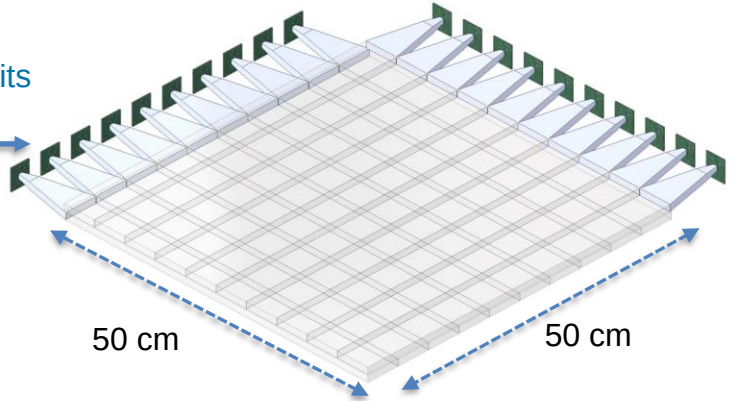
BIOSPHERE

WP 1

Novel detector for cosmic muons



- Solid angle adjustment
- Angular distribution of muons
- Pixelated
- Mobile



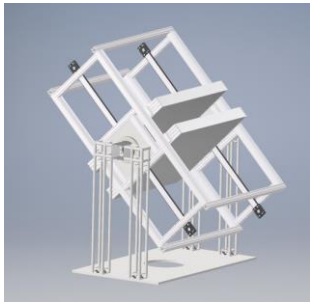
Design and overall construction

G. Winterbottom, B. Pullner (PTB)

Detector unit development

V. Dangendorf, M. Weierganz (PTB)

Research projects: Overview



The research projects have the purpose to develop new measurement devices, methods and metrological infrastructure to:

- Accurately quantify the environmental radiation
- Support the radiological emergency management
- Investigate the correlations between ionizing radiation in the environment, climate, anthropogenic emissions and activities and health

Many thanks to …

Besonderer Dank gilt meinen Kolleginnen und Kollegen in der PTB und den Partnern in verschiedenen Projekten

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Jürgen Roth
Beate Lambertsen
Volker Dangendorf
Ulrich Giesen
Frank Langner

Oliver Hupe
Annette Röttger
Stefan Neumaier
Harald Dombrowski

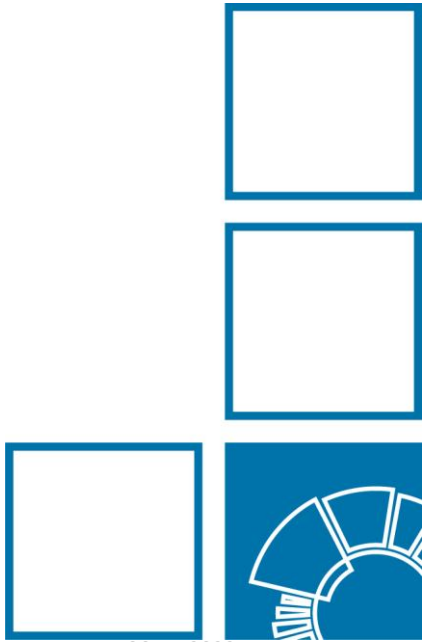
The BIOSPHERE consortium

The project 16ENV04 Preparedness has received funding from the EMPIR programme co-financed by the participating states and from the European Union's Horizon 2020 research and innovation programme.

The project 19ENV02 RemoteALPHA has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

The project 21GRD02 BIOSPHERE has received funding from the European Partnership on Metrology, co-financed by the European Union's Horizon Europe Research and Innovation Programme and by the Participating States.

Thank you!



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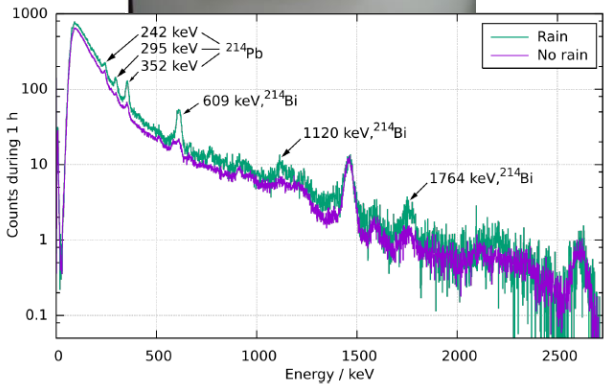
Measurement equipment for environmental monitoring

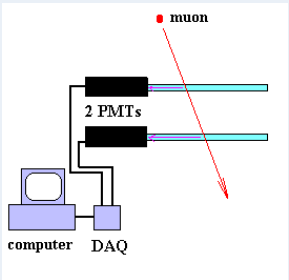
Spectro-dosemeter systems based on scintillators (PTB development)



Spectra measured with a SrI_2 Detector

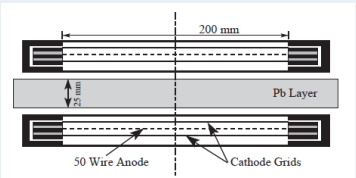
R. Dąbrowski et al 2017 JINST 12 P10005

Muon Detectors



DECOS (PTB development)

Two detectors with large area scintillators measure in coincidence



MUDOS (Eigene Etwicklung)

Two *cylindrical proportional chambers* measure in coincidence

Regular radiation detectors

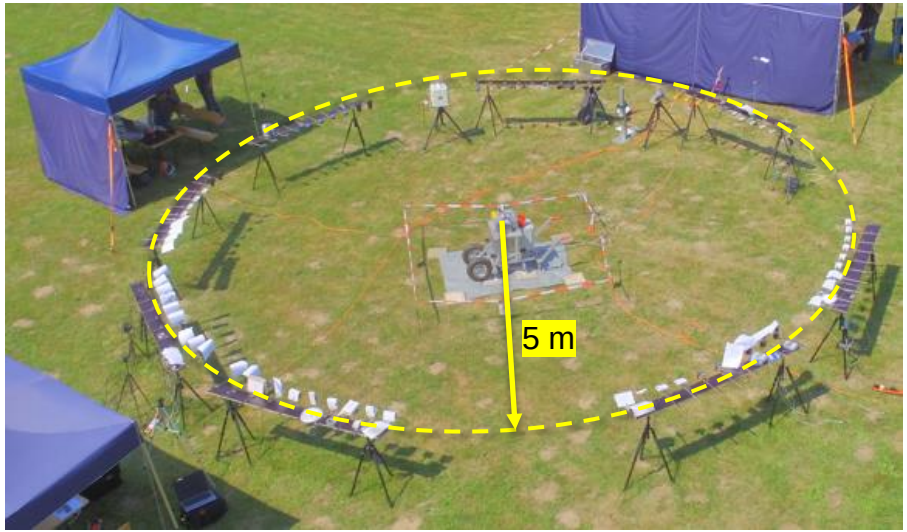
- High pressure ionization chambers,
- Geiger-Müller counter
- Neutron probes

Radon detection systems

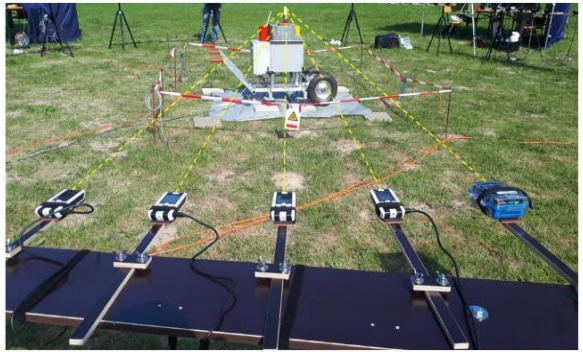
Non-governmental networks for radiological monitoring

Testing the capability of MINNs

MINN ⇨ measuring instruments used in the non-governmental networks



PTB reference site, simulation of a radioactive cloud



*Reference radiation fields (137Cs, 60Co und 226Ra), generated in a **photon irradiation facility („Wolkenmaschine“)** provide the opportunity to investigate and determine the reponse of detectors to small artificial dose rate.*

PREPAREDNESS

V. Morosh *et al.*, Radiation Measurements 143 (2021) 106580.

EURAMET

Emergency protection: Optical measurements of alpha emitters

EMPIR Projekt 19ENV02 **RemoteALPHA**
(01.09.2020-31.08.2023)

Coordination: PTB

Goals

Support of emergency management and strategies for radiological accidents with alpha-emitting radionuclides (Richtlinie 2013/59/EURATOM)

- Development of novel optical systems to remotely detect and quantify large area contamination with alpha emitters
- Development of novel calibration systems and a metrological methods to support the introduction of new technologies for the radiological emergency management

Partners

Physikalisch-Technische Bundesanstalt Braunschweig und Berlin

Budapest Főváros Kormányhivatala

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Szent István University

RemoteALPHA

The project 19ENV02 RemoteALPHA has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

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Emergency protection: Optical measurements of alpha emitters

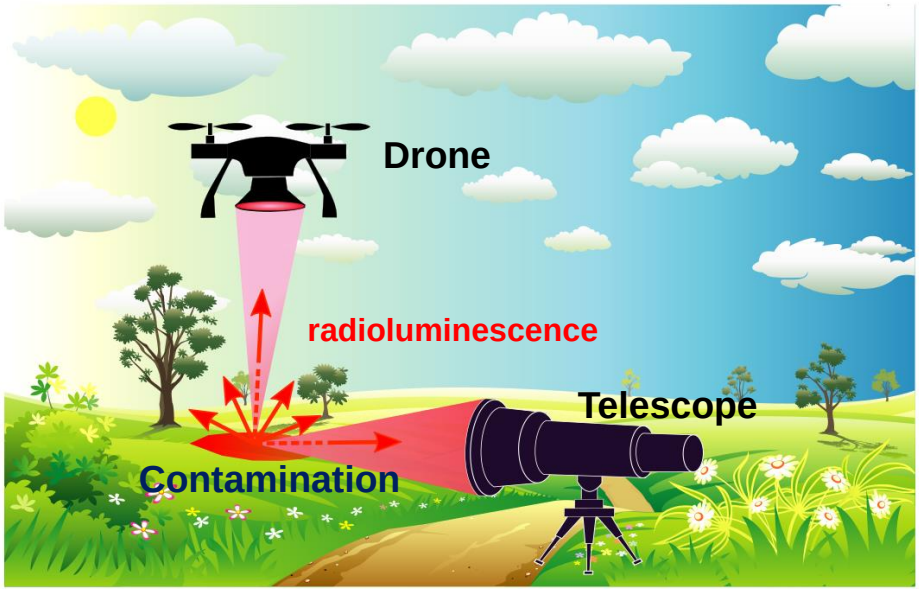
Emergency measures and strategies to support in case of radiological emergencies with alpha emitters

http://www.argonelectronics.com/blog/the-value-of-applied-learning-for-radiation-safety-training

Disadvantages of regular methods to detect alpha emitters in the environment:

- Require measurements very close to the contaminated surface,
- Expose the workers to other dangers and risks such as other kinds of radiation, fire, etc,
- Time-consuming scan of large contaminated areas.

Emergency protection: Optical measurements of alpha emitters



<u>Concept</u>: High energy alpha particles ionize the air (mostly nitrogen molecules). Air molecules emit fluorescence light (radioluminescence) in the UV range between 200 nm and 400 nm.
The atmosphere serves as scintillator.

<u>Advantages of optical detection:</u>

- Users can stay outside of radiation field,
- Efficient scanning of large areas.

<u>Reichweite in Luft</u>

Alpha emitters → 0,04 m
UV-light → 500 m

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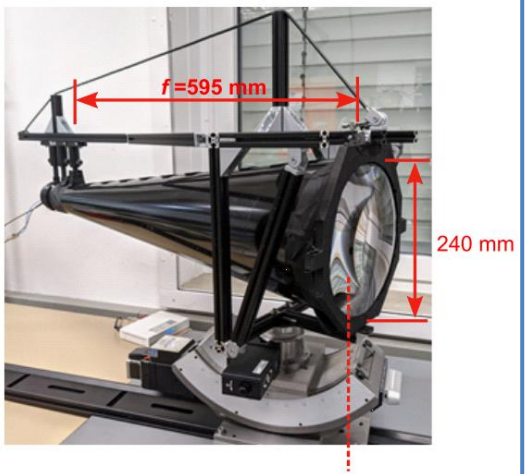
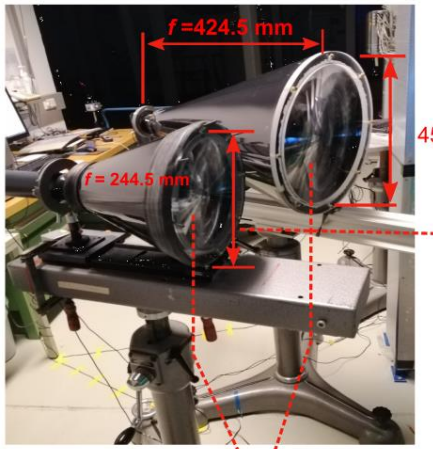
Emergency protection: Optical measurements of alpha emitters

Novel radioluminescence detection systems to remotely detect alpha emitting radionuclides



UV fused silica lens



PMMA Fresnel lens

Fresnel-Lense system on a drone to map contamination from a distance

M. Luchkov, F. Krasniqi (PTB, FB 6.3)
V. Dangendorf (PTB, FB 6.1)
U. Giesen (PTB, FB. 6.4)

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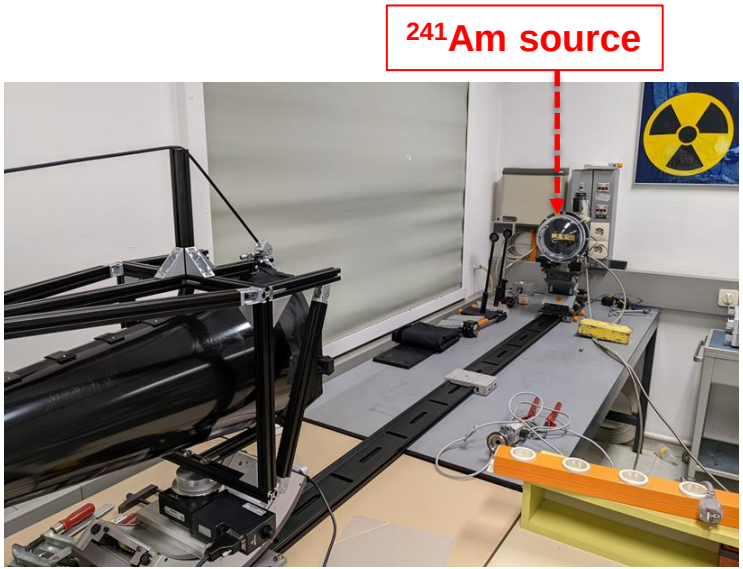
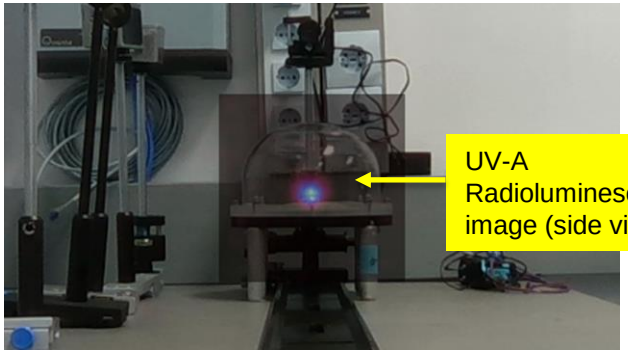
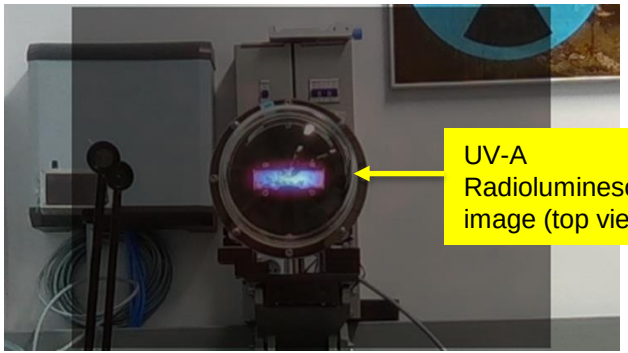
Emergency protection: Optical measurements of alpha emitters



Testing of optical detection systems with a Am-24 source (49 kBq/cm^2) in a distance of 2 m.





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M. Luchkov, V. Dangendorf, U. Giesen, F. Langner, C. Olaru, M. Zadehrafi, A. Klose, K. Kalmankoski, J. Sand, S. Ihantola, H. Toivonen, C. Walther, S. Röttger, M.-R. Ioan, J. Toivonen and F. S. Krasniqi, *Novel optical technologies for emergency preparedness and response: mapping contaminations with alpha-emitting radionuclides*, submitted to Nucl. Instrum. Methods Phys. Res. A. (2022).

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