Italian National Agency for New Technologies, Energy and Sustainable Economic Development

"Passive dosimetry measurements used in the aftermath of a radiological accident in the framework of "PREPAREDNESS" EMPIR project"

5TH NERIS WORKSHOP, 3-5 APRIL 2019, ROSKILDE (DENMARK)

SESSION 3: RADIOLOGICAL IMPACT ASSESSMENT DURING ALL PHASES OF NUCLEAR AND RADIOLOGICAL EVENTS

NERIS

G. Iurlaro, **Ž. Knežević**, *H. Dombrowski, M. Majer, F. Mariotti, B. Morelli, L. Campani, L. Sperandio*

PREPAREDNESS

Metrology for mobile detection of ionising radiation following a nuclear or radiological incident.

Overview

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- Preparedness EMPIR Project
- WP4 Passive dosimetry
- Environmental radiation monitoring with passive dosimetry systems
- Operational quantities
- Radiological protection of the environment
- Literature study on passive dosimetry measurements used in the aftermath of a radiological accident
- Preliminary results
- Conclusion

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Preparedness EMPIR Project

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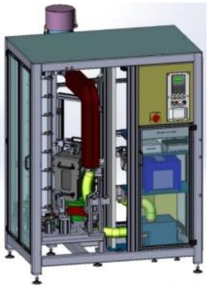
Field of application:

- Nuclear or other radiologically relevant incidents or accidents.

Objectives:

- The protection of the public against ionising radiation and radioactive contaminations.
- The increase of the confidence of the public in governmental emergency preparedness.

- The development of methods to collect reliable radiological data on affected and contaminated areas to support radiation protection authorities and other decision makers.



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Metrology for mobile detection of ionising radiation following a nuclear or radiological incident.

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Preparedness EMPIR Project

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Participants	Short Name	Country
6 Internal Funded Partner	PTB	Germany
	CMI	Czech Republic
	IJS	Slovenia
	NPL	United Kingdom
	IRB	Croatia
	VINCA	SeIRBa
10 External Funded Partner	AUTH	Greece
	BfS	Germany
	CLOR	Poland
	EHU	Spain
	ENEA-IRP	Italy
	JRC	Europe
	Kromek	United Kingdom
	MTI	Czech Republic
	NUVIA	Czech Republic
	UPC	Spain
1 Unfunded Partner	SCK•CEN	Belgium

Preparedness consortium comprises 17 institutions from 11 European countries

M9 Meeting- Ispra 14-15 May 2018 – Group photo

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Preparedness EMPIR Project

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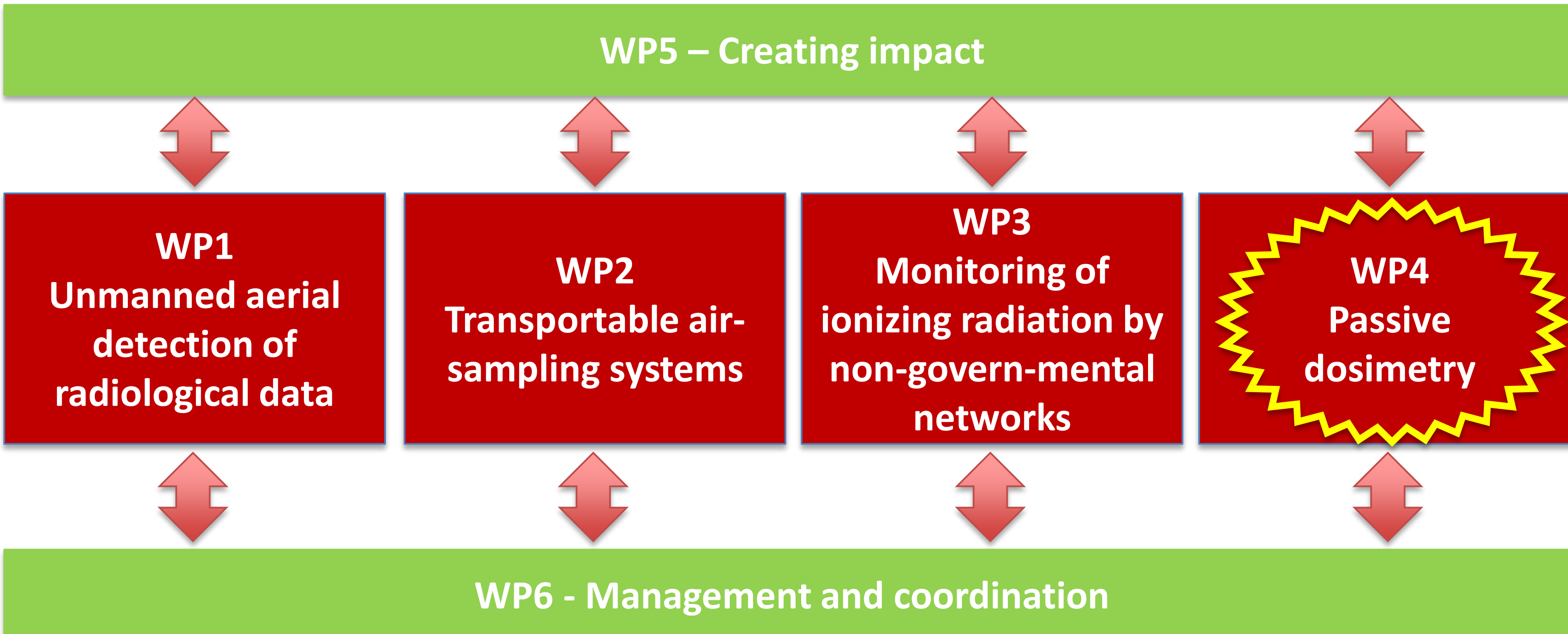
Diagram of the relationships between the work packages of the Joint Research Project (JRP)



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WP4 Passive dosimetry

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WP4 Objective:

To establish stable and reproducible procedures to measure the ambient dose equivalent *H*(10)* using passive dosimeters in order to harmonize passive area dosimetry across Europe.

Messen ▪ Forschen ▪ Wissen

Vinca Institute of Nuclear Sciences

Ruđer Bošković Institute

Centralne Laboratorium Ochrony Radiologicznej

ARISTOTLE UNIVERSITY OF THESSALONIKI

Italian National Agency for New Technologies, Energy and Sustainable Economic Development

Six Active partners in WP4:

- Physikaisch-Technische Bundesanstait **(WP leader)**
- Vinca Institute of Nuclear Sciences, University of Belgrade
- Ruđer Bošković Institute
- Centralne Laboratoriun Ochrony Radiologicznej
- Aristotelio Panepistimio Thessalonikis
- Italian National Agency for New Technologies, Energy and Sustainable Economic Development

WP4 Passive dosimetry

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4 Tasks of WP4

4.1: Investigation of the current status of passive environmental dosimetry

4.2: Technical and methodological investigations on passive area dosimetry

4.3: Measurement of the ambient dose equivalent using electret ion chambers

4.4: Harmonisation of European dose rate measurement procedures using passive dosemeters

WP4 Passive dosimetry

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Investigation of the current status of passive environmental dosimetry

- **Collation of data** of existing surveys concerning the use of passive *H**(10) dosimetry systems in Europe (information on calibration and verification procedures of passive area dosimetry systems and their traceability to primary standards).
- **Literature study on passive dosimetry** used in the aftermath of a radiological accident (metrological aspects: traceability, uncertainty calculation and methodical descriptions).
- **Collation of a list** of published detection limits for different detector types (e.g. based on TL, RPL or OSL) to gather information on uncertainties stated by measuring services).
- **Intercomparison** of at least 15 passive H*(10) area dosimetry systems used for environmental monitoring (irradiations at PTB reference sites for environmental radiation & cosmic radiation, PTB gamma irradiation facility, UDO II) and **evaluation of results**.

WP4 Passive dosimetry

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Technical and methodological investigations on passive environmental dosimetry

- Analysis of uncertainties which govern the detection limits in different stages of the measuring cycle and **development of methods** to lower the **detection limits.**
- **Investigation of** more than 5 different **detector holder types** with respect to their influence on the dosimeter response in terms of $H^*(10)$ and v**erification** by Monte Carlo simulations.
- **Study of methods** to expose passive dosemeters in the environment (**'site criteria')** in routine operation & in emergency situations (ideal measuring sites).
- **Irradiation of 10 different dosimeter types** under laboratory conditions for investigating :
  - the energy response,
  - the response to natural gamma radiation,
  - the linearity and angular dependence of the response.

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Environmental radiation monitoring with passive dosimetry systems

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Routine

Many national measuring bodies in Europe and worldwide use passive dosimetry systems **to survey nuclear installations** at the borders of the restricted territories **in order to verify the dose level** and **to measure increment of dose** arising from artificial ionizing radiation, with the respect to allowed dose limit.

Emergency

In the early phase of a nuclear/radiological accident, the main focus is to bring the facility/site to a stable condition and to ensure the safety of workers, members of the public .

Afterwards, the use of passive dosimetry systems for environmental radiation monitoring **in the aftermath of a radiological accident** (i.e. decommissioning and/or remediation phases) could produce important data for the activities of decommissioning, remediation and for **the radiation protection of the public**.

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Operational quantities

Operational quantities for area and individual monitoring of external exposures have been defined by ICRU.

Application of operational dose quantities for monitoring of external exposures

Task	Operational dose quantities for	
	area monitoring	**individual monitoring**
Control of effective dose	Ambient dose equivalent , H*(10)	Personal dose equivalent, Hp(10)
Control of doses to the skin, the hands and feet and the lens of the eye	Directional dose equivalent, H'(0.07, Ω)	Personal dose equivalent, Hp(0,07)

H*(10) and $H_p(10)$ are designed for monitoring strongly penetrating radiation, e.g. photons (above about 12 keV) and neutrons, while $H_0(0.07, X)$ and $H_p(0.07)$ are applied for monitoring low-penetrating radiation, e.g., beta particles.

Overview

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- Protection and operational quantities
- Radiological protection of the environment
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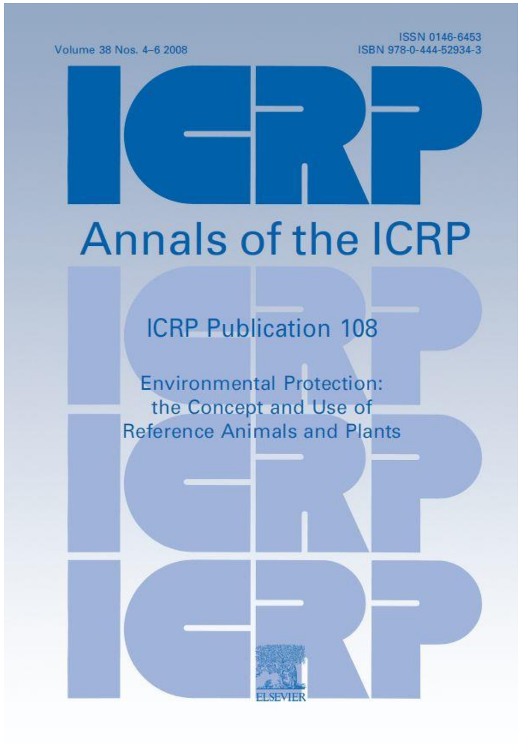
Interest in the protection of the environment has greatly increased in recent years, in relation to all aspects of human activity.

ICRP Publication 108 - Environmental Protection – the Concept and Use of Reference Animals and Plants (ICRP,2008).

This publication introduces the concept of Reference Animals and Plants, and defines a small set. It discusses their pathways of exposure, and collates and discusses the adequacy of the best-available data relating to their dosimetry at different stages of their life cycles.



Overview

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- Dose for public exposure (generalities)
- Operational quantities
- Radiological protection of the environment
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Literature study on passive dosimetry measurements for radiological monitoring

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- ✓ IRB together with ENEA performed a ***"Literature study on passive dosimetry measurements used in the aftermath of a radiological accident"***
- ✓ The study tried to find the metrological aspects traceability, uncertainty calculation and methodical descriptions.
- ✓ The study includes 27 publications and tried to collect public and available information on passive dosimetry measurements and monitoring by mean of examples.

IRB Ruđer Bošković Institute

ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development

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Literature study on passive dosimetry measurements for radiological monitoring

NERIS

	Author and Title	Reference
1.	P. Aramrun, N. A. Beresford, M. D. Wood, **Selecting passive dosimetry technologies for measuring the external dose of terrestrial wildlife**	Journal of Environmental Radioactivity, 182, 128-137 (2018)
2.	A.K. Singh, S.N. Menon, S.Y. Kadam, D.K. Koul, D. Datta, **OSL properties of three commonly available salt brands in India for its use in accident dosimetry**	Nucl. Inst. and Meth.in Phys. Res. B, 419, 15 Pages 38-43 (2018)
3.	J. Ayobami Ademola, **Luminescence properties of common salt (NaCl) available in Nigeria for use as accident dosimeter in radiological emergency situation**	Journal of Radiation Research and Applied Sciences, Vol.10, Issue 2, Pages 117-121 (2017)
4.	P. Strand, S. Sundell-Bergman, J.E. Brown, M. Dowdall, **On the divergences in assessment of environmental impacts from ionising radiation following the Fukushima accident**	Journal of Environmental Radioactivity, 169–170, 159-173 (2017)
5.	K.Stark, J.M. Goméz-Ros, J. Vives i Batlle, L. Hansen, T. G. Hinton, **Dose assessment in environmental radiological protection: State of the art and perspectives**	Journal of Environmental Radioactivity, 175–176, 105-114, (2017)

Literature study on passive dosimetry measurements for radiological monitoring

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	Author and Title	Reference
6.	N.A. Beresford, S. Fesenko, A. Konoplev, J.T. Smith, G. Voigt, **Thirty years after the Chernobyl accident – 30 key papers published in the Journal of Environmental Radioactivity**	Journal of Environmental Radioactivity, 157, 38-40 (2016)
7.	D. Ekendal, B. Bulanek, L. Judas, **Comparative measurements of external radiation exposure using mobile phones, dental ceramic, household salt and conventional personal dosemeters**	Radiation Measurements, Vol.72, Pages 60-65 (2015)
8.	V.V. Chumak, **Retrospective dosimetry of populations exposed to reactoraccident: Chernobyl example, lesson for Fukushima**	Radiation Measurement 55, 3-11 (2013)
9.	V. Kortov, Yu. Ustyantsev, **Chernobyl accident: Causes, consequences and problems of radiation measurements**	Radiation Measurements, 55, Pages 12-16 (2013)
10.	C.Woda, J. C. Kaiser, L. Urso, M. Greiter, **An environmental BeO-OSL dosimeter for emergency response**	Radiation Measurements, Vol 47,Issue 8, Pages 609-613 (2012)

Literature study on passive dosimetry measurements for radiological monitoring

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	Author and Title	Reference
11.	C. Bernhardsson, S. Matskevich S. Mattsson C. Rääf, **Comparative measurements of the external radiation exposure in a 137Cs contaminated village in Belarus based on optically stimulated luminescence in NaCl and thermoluminescence in LiF**.	Health Phys. 103(6):740-9. (2012)
12.	C.Bernhardsson, I.Zvonova, C.Raaf, S.Mattsson, **Measurements of long-term external and internal radiation exposure of inhabitants of some villages of the Bryansk region of Russia after the Chernobyl accident**	Science of the total Environment, Vol 409, Issue 22, Pages 4811-4817 (2011)
13.	M. Balonov, A. Bouville, **Radiation Exposures Due to the Chernobyl Accident**	Encyclopedia of Environmental Health, Pages 709-720 (2011,)
14.	H. Nanto, Y.Takei and Y. Miyamoto**, Environmental Background Radiation Monitoring Utilizing Passive Solid Sate Dosimeters (chapter 8)**	Book Environemntal monitoring, DOI: 10.5772/27382 ISBN 978-953-307-724-6, publisher InTech, 121-136 (2011)
15.	E.J. Antonio,T.M. Poston, B.A. Rathbone, **Thermoluminescent Dosimeter Use for Environmental Surveillance at the Handford Site, 1971-2005**	PNNL-192017 (2010)

Literature study on passive dosimetry measurements for radiological monitoring

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	Author and Title	Reference
16.	J.H. Lee, M.S. Lin, S.M. Hsu, I.J. Chen, C.F. Wang, **Dosimetry characteristics and performance comparisons: Environmental radiophotoluminescent glass dosemeters versus thermoluminescent dosemeters**	Radiation Measurements, 44, I 1, Pages 86-91 (2009)
17.	M. Ranogajec Komor, **Passive Solid State Dosimeters In Environmental Monitoring (chapter)**	New Techniques for the Detection of Nuclear and Radioactive Agents, NATO Security through Science Series B: Physics and Biophysics DOI: 10.1007/978-1-4020-9600-6_7,
18.	M. Ranogajec-Komor, Ž. Kneževic, S. Miljanic, B. Vekic, **Characterisation of radiophotoluminescent dosimeters for environmental monitoring**	Radiation Measurements 43 392–396 (2008)
19.	M.J.Madruga, **Environmental radioactivity monitoring in Portugal**	Applied Radiation and Isotopes 66, pages 1639-1643 (2008)
20.	I.H-Taam, L.A.R. da Rosa, V.R. Crispim, **TLD environmental monitoring at the Institute of Nuclear Engineering in Brazil**	Applied Radiation and Isotopes 66, pages 1229-1234 (2008)

Literature study on passive dosimetry measurements for radiological monitoring

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	Author and Title	Reference
21.	M. Budzanowaski, P. Olko, B. Obryk, E. Ryba, A. Nowak, **Long-term environment monitoring based on MTS-N (liF:Mg, Ti) and MCP-N(LiF:Mg,Cu,P)** thermoluminescent detectors	Radiation Measurements 38 821-824 (2004)
22.	M. R. Komor, **Thermoluminescence Dosimetry – Application in Environmental Monitoring**	Radiation Safety Management Vol.2, N.1 (2-6) (2002)
23.	I.P.Los, M.G.Buzinny, **Physical, technical and methodical problems of exposure rate measurements on the territories contaminated as a result of Chernobyl power station accident**	IAEA-SM-306/142P Poster presentation
24.	E.H.Haskell, **Accident dosimetry using environmental materials: the role of thermoluminescence**	Nucl. Tracks Radiat. Meas., Vol. 21, n1, pages87-93 (1993)
25.	I.Feher, **Experience in hungary on the radiological consequences of the Chernobyl accident**	Environment International, Vol 14, pp113-135(1988)
26.	T.W.Wang, J.K.Gone, **Environmental Radiation Monitoring Program of the Institute of Nuclear Energy Research in Taiwan**	P-4a-263
27.	G.De Planque, T.F.Gesell, **Thermoluminescence Dosimetry – Environmental Applications**	J.Appl.Radiat.Isot., Vol 33, Pages 1015-1034(1982)

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Preliminary results

This study collected information from more than 10 scientific journals.

Name of Scientific Journal	N° of publications
Applied Radiation and Isotopes	2
Environment International	1
Health Physics	1
The International Journal of Applied Radiation and Isotopes	1
Journal of Environmental Radioactivity	4
Journal of Radiation Research and Applied Sciences	1
Nuclear Instruments and Methods in Physics Research Section B	1
Nuclear Tracks Radiation Measurements	1
Radiation Measurements	7
Radiation Safety Management	1
Science of the total Environment	1
Other Publications	6
Total	**27**

Preliminary results

It is possible to classified the articles in 6 categories

Main theme	N° of publications
Overview on passive dosimetry for environmental monitoring	4
Study of dosimeters for accident and retrospective dosimetry	6
Measurement by dosimeters and retrospective dosimetry after nuclear accident	9
Monitoring of nuclear site and environment	4
Dosimetry measurements on animals	2
No data on passive dosimetry systems	2
Total	**27**

Preliminary results

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Dosimetry systems/ Technique	Dosimetry for animals	Material for retrospective dosimetry	Dosimeters for measurement after nuclear accident	Monitoring of nuclear site and environment
Thermoluminescent dosimeter - TLD	xxx	xxxxxx	xxxx	xxxxxxx
Radiophotoluminescent dosimeter- RPLD	xxxx	x		xx
Optically stimulated luminescent dosimeter- OSL	xx	xxx	x	
Direct ion storage -DIS		x		
Electron paramagnetic r esonance - EPR	x			
Silicon diode electronic dosimeter - SDED		x		

Preliminary results

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Example of an article in which metrological aspects traceability, uncertainty calculation and methodical descriptions are mentioned (N°21).

<table>
<tr><td>Metrological aspects</td><td colspan="2">Calibration in INP accredited calibration laboratory in terms of air kerma free-in-air.</td></tr>
<tr><td>Uncertainty calculation</td><td colspan="2">The absorbed dose in air at the measurement site was determined from the mean readout of three TL detectors. The estimated relative uncertainty of the dose value given for any site does not exceed 5%.</td></tr>
<tr><td rowspan="4">Methodical descriptions</td><td>Site</td><td>For outdoor measurements the dosemeters are mounted on a steel rod at a height of 1 m above ground level.</td></tr>
<tr><td>Measurements periods</td><td>Quarterly periods</td></tr>
<tr><td>Dosimeter type</td><td>Dosimetry cards KD-86 or KD-99, each containing three standard MTS-N or three high-sensitive MCP-N detectors</td></tr>
<tr><td>Reader system</td><td>Two ACARD97 automatic TL readers</td></tr>
</table>

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Conclusion

The literature overview showed that there are a very few studies dealing with the specific topics on “passive dosimetry” in the aftermath of a radiological event. It is possible to suppose that the use keywords and common search machine is a weakness of this kind literature study and other articles could be identified by a new random search.

In conclusion, if solid state systems are used for long-term environmental monitoring, harmonized methods are necessary and a detailed knowledge of the performance of the passive dosimetry systems is required in order to allow reliable measurements even at low dose levels.

Therefore, the EMPIR “Prepardness “ project aims at the implementation of stable and reproducible procedures for the measurement of ambient dose equivalent rates by using passive dosimeters and the improvement of the necessary metrological infrastructure in Europe.

Conclusion

Currently, all the partners all involved in the technical and methodological investigations on passive area dosimetry using their facilities.

Intercomparison of more than 15 passive H*(10) area dosimetry systems used for environmental monitoring: the measurement campaign comprises the irradiation of dosimeters under reference condition at PTB reference sites for environmental radiation & cosmic radiation.

Outcome: Important dosimetric characteristics of the dosemeters and typical precision which can be reached in this field of passive dosimetry.

Conclusion

Currently all the partners involved in the technical and methodological investigations on passive environmental dosimetry with their facility.

ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development	**Energy response** (8 X-ray quality, Cs-137, Co-60)
CLOR Centralne Laboratorium Ochrony Radiologicznej	**Natural spectrum** (Ra-226, Cs-137 and Co-60)
Vinca Institute of Nuclear Sciences	**Angular dependence** (0°,30°,60°,90°, 180°)
RB	**Dose dependence** (from ≈150 μSv to1Sv)

The results of all technical and methodological investigation will be taken in account in the development of recommendations for the harmonization of passive area dosimetry systems.

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Ruđer Bošković Institute

Vinca Institute of Nuclear Sciences

PTB Messen · Forschen · Wissen

Centralne Laboratorium Ochrony Radiologicznej

ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development

WP 4 Leader: *H. Dombrowski*

List of WG4 Partners:

Ž. Knežević, M. Majer, G. Iurlaro,

M. Zivanovic, Z. Baranowska, A. Clouvas

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The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Thank you for attention!

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Protection and Operational quantities

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Protection Quantities

The body-related protection quantities (equivalent dose and effective dose) are not measurable in practice and therefore cannot be used directly as quantities in radiation monitoring.

Operational Quantities

Operational quantities are measurable quantities aimed at providing an estimate or upper limit for the value of the protection quantities related to an exposure of persons under most irradiation conditions.

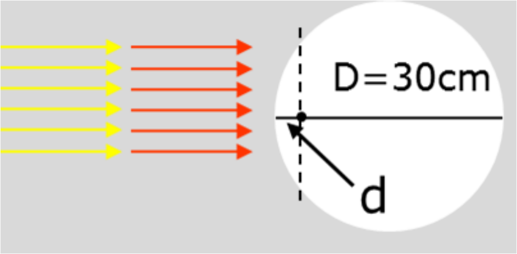
The Operational Quantities are used in practical applications for monitoring and investigating situations involving external exposure. Different operational dose quantities are required for different tasks in radiological protection. These include:

- area monitoring for controlling the radiation (in workplaces and environment),
- area monitoring for defining controlled or restricted areas,
- individual monitoring for the control and limitation of individual exposures.

The unit of Operational Quantities is joule per kilogram and its special name is sievert (Sv).

Operational quantity- H*(10)

" The ambient dose equivalent, H*(10), at a point in a radiation field, is the dose equivalent that would be produced by the corresponding expanded and aligned field in the ICRU sphere at a depth of 10 mm on the radius vector opposing the direction of the aligned field."



76,2 % oxygen, 11,1 % carbon; 10,1 % hydrogen; 2,6 % nitrogen

The ambient dose equivalent fulfils the aim of providing a conservative estimate or upper limit for the value of the limiting quantities.

Operational quantity- Hp(d)

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The personal dose equivalent, H_p(d) is the dose equivalent in soft tissue (commonly interpreted as the ‘ICRU sphere’) at an appropriate depth, d, below a specified point on the human body. The specified point is usually given by the position where the individual’s dosimeter is worn assuming uniform whole body exposure.

For the assessment of effective dose, Hp(10) with a depth d = 10 mm is chosen, and for the assessment of the dose to the skin and to the hands and feet the personal dose equivalent, Hp(0.07), with a depth d = 0.07 mm, is used. A depth d = 3 mm has been proposed for the rare case of monitoring the dose to the lens of the eye.

Absorbed dose, D

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In radiation biology, clinical radiology, and radiological protection the absorbed dose, D, is the basic physical dose quantity, and it is used for all types of ionising radiation and any irradiation geometry. The fundamental dose quantity given by

$$D = \frac{d\bar{\varepsilon}}{dm}$$

where $d\bar{\varepsilon}$ is the mean energy imparted to matter of mass dm by ionising radiation.
The SI unit for absorbed dose is joule per kilogram (J kg^{-1}) and its special name is gray (Gy).

Absorbed dose is a measurable quantity and primary standards exist to determine its value.