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DOSE RATE DATA OF MEASURING INSTRUMENTS USED IN NON-GOVERNMENTAL NETWORKS (MINNs) IN THE FRAMEWORK OF PREPAREDNESS EMPIR PROJECT

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

EUROSAFE | 2019

Summary

- EMPIR-16ENV04 PREPAREDNESS Project
- WP3: Monitoring of ionizing radiation by non-governmental networks
- Monitoring and measuring – H*(10)
- Overview on non-governmental networks in Europe
- Measuring Instruments used in non-governmental Networks (MINN) in Europe
- Metrological investigation of MINNs (Measuring Instruments used in non-governmental Networks) data
- Conclusions

EMPIR-16ENV04 “PREPAREDNESS” Project

- 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.

- Instruments:

  Reliable radiological data on affected and contaminated areas to support radiation protection authorities and other decision makers

EMPIR-16ENV04 “PREPAREDNESS” Project

Participants	Short Name	Country
6 Internal Funded Partner	PTB	Germany
	CMI	Czech Republic
	IJS	Slovenia
	NPL	United Kingdom
	IRB	Croatia
	VINCA	Serbia
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

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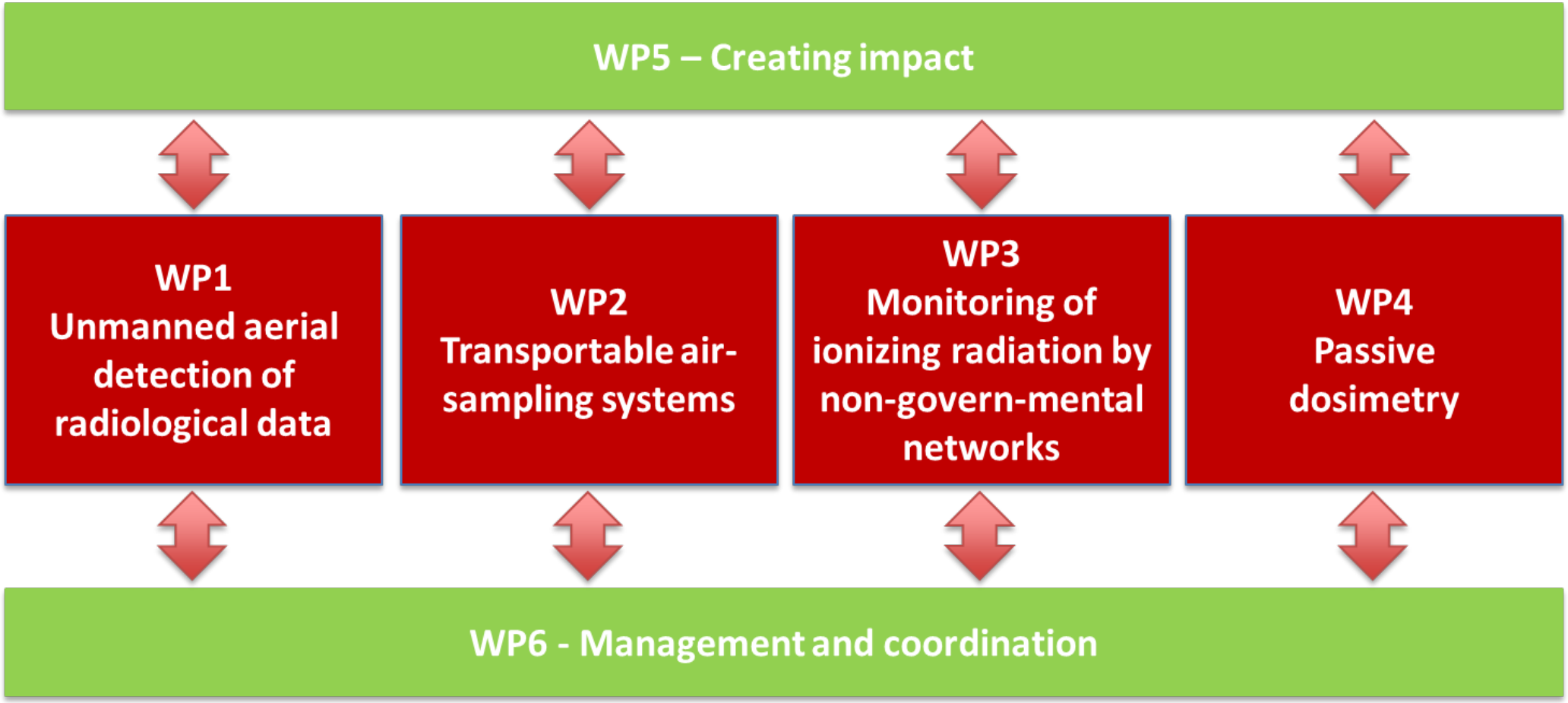
EMPIR-16ENV04 “PREPAREDNESS” Project



WP3: Monitoring of ionizing radiation by non-governmental networks

- In a relevant incident/accident with radiological risk the levels of **ambient dose equivalent rate** provide essential information about the consequences of the progression of the radioactive cloud.
- This information will allow **appropriate countermeasures** by decision makers and reduce the risk of exaggerated actions and preventable follow-up costs.
- The Work Package 3 of the project: "**Monitoring of ionising radiation by non-governmental networks**" aims to establish a metrological basis to support this work.

WP3: Monitoring of ionizing radiation by non-governmental networks

- Evaluation of existing radiation measuring instruments and practices used in non-governmental monitoring networks.
- Feasibility study on the use of non-official dosimetry data for preparedness purposes.
- Development of prototypes for instruments to be used in both non-governmental and state-owned monitoring networks.

Monitoring and measuring – H*(10)

Environmental dose rate

$$\dot{H}(10)_{MINN} = \dot{M}_0 + q_{SCR} \cdot \dot{H}^*(10)_{ref,SCR} + q_{terr} \cdot \dot{H}^*(10)_{ref,,terr} + q_{art} \cdot \dot{H}^*(10)_{ref,art}$$

Inherent background

Secondary cosmic radiation

Terrestrial radiation

Artificial radiation

$\dot{H}^*(10)_{Art} = \dot{H}^*(10)$

$\dot{M}_0$= inherent background or self-effect of the instrument

q_{SCR} =response to secondary cosmic radiation

q_{TR} =response to terrestrial radiation

q_{Art}=response to artificial radiation (function on E and direction of radiation)

$\dot{H}^*(10)_{ref,SCR}$ =ambient dose equivalent rate due to secondary cosmic radiation

$\dot{H}^*(10)_{ref,terr}$ =ambient dose equivalent rate due to terrestrial radiation

$\dot{H}^*(10)_{ref,art}$ = ambient dose equivalent rate due to artificial radiation

Monitoring and measuring – H*(10)

Radioactivity monitoring networks are usually designed for two main purposes:

- to detect anomalies for early-warning and
- to manage accidents.

Depending on the meteorological conditions, airborne radioactivity can be transported over several hundreds of kilometres in a few hours.

Advantages and disadvantages of gamma dose rate measurements:

Advantages	Disadvantages
Technically simple, robust, relatively cheap (therefore high spatial resolution possible). Short sampling and reaction time (high temporal resolution).	Does not distinguish between Nuclides (no spectroscopic measurements). Does not distinguish between location of the source (cloud or ground).

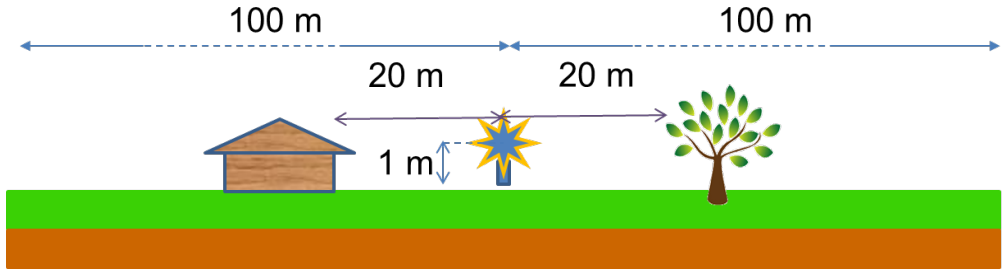
Monitoring and measuring – H*(10)

The response of a particular detector depends on the “geometry” of its location:

- topography,
- vicinity of buildings and vegetation (trees),
- the nature of the ground below the detector, etc.

Recommended siting criteria for ambient dose rate measurements:

- the probe shall “ideally” be located in the middle of a flat and even meadow at 1 m above ground;
- the horizon of the probe shall not be shielded by buildings or trees within a radius of at least 20 m;
- smooth ground surface of grassland within a radius up to 100 m free of irregularities.



Monitoring and measuring – H*(10)

Alert and alarm thresholds

Two principal different philosophies could be implemented for defining thresholds above which some kind of alarm is triggered:

Fixed /absolute thresholds	Relative thresholds
Values of ambient dose rate, irrespective of the local baseline radiological conditions which depend, e.g., on the altitude of the site above sea level or the geological conditions (concentration of natural radionuclides in the ground). This means that in different locations different additional dose rates are needed to trigger an alert or alarm.	Values of ambient dose rate, which honour the local natural radiation environment. In practice, this can be implemented by setting the threshold: • to a multiple of a (however defined) temporal average which is characteristic for the site, or , • to a multiple of standard deviations above the average, or • to a fixed value above average.

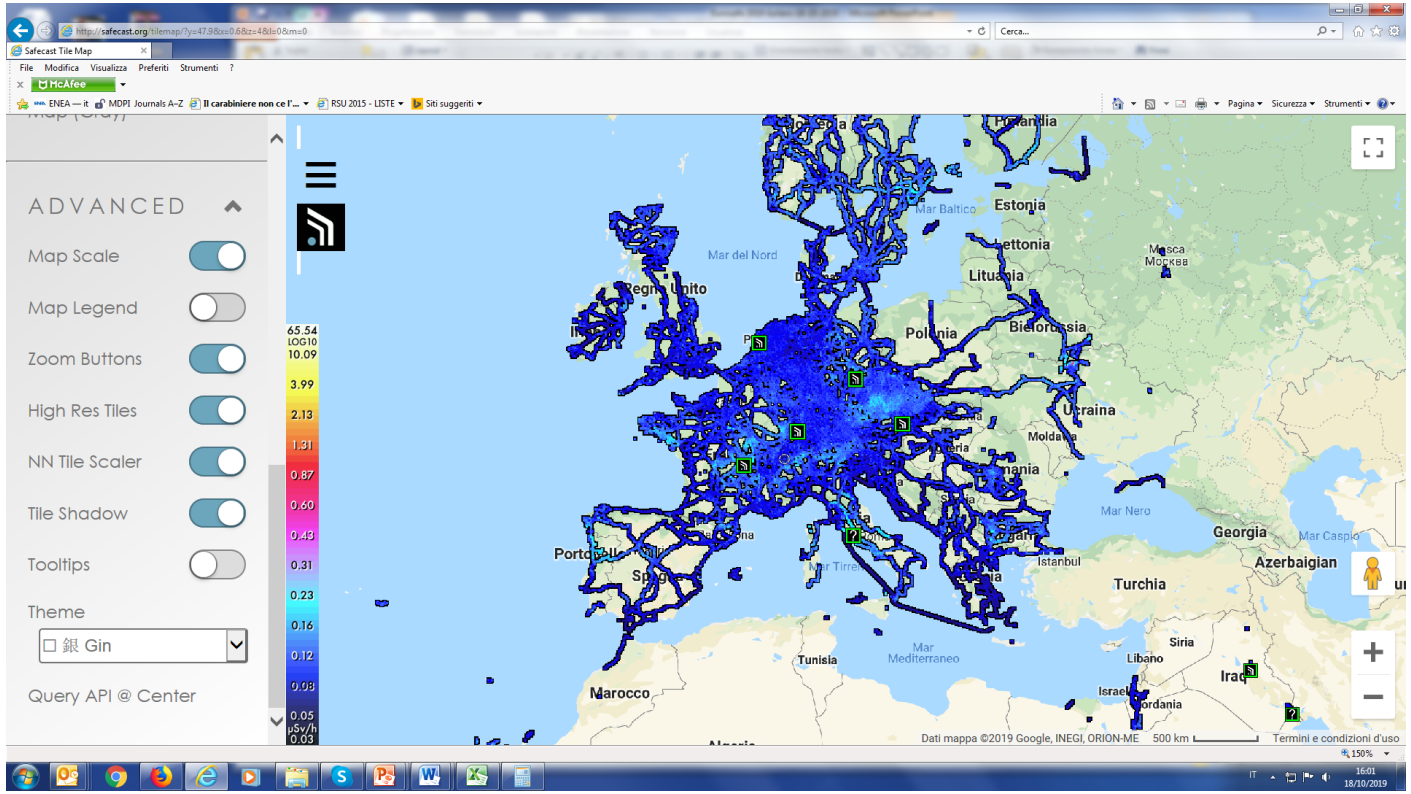
Overview on non-governmental networks in Europe

Network	Responsible commercial company (website)	Networks Website
Safecast	Non-governmental organization	https://blog.safecast.org/
GMC Map	GQ Electronics (USA) (http://www.gqelectronicsllc.com)	http://www.gmcmap.com/index.asp
Radmon	Creative Systems Inc. (USA) (http://www.creativesysinc.com)	http://radmon.org/
Radation network	Mineralab, LLC (USA) (http://www.mineralab.com/)	http://radiationnetwork.com/
Radioactive@home	Non-governmental organization (BOINC Polska Foundation / Poland)	http://radioactiveathome.org/en/
uRadMonitor	MagnaSCI (Romania) (http://www.magnasci.com/)	https://www.uradmonitor.com/

All the considered networks are private companies except for Safecast and Radioactive@home that are non-governmental organization (NOG), this means that they are a non-profit organization

Overview on non-governmental networks in Europe

Safecast is a global volunteer-centered citizen science project that was born immediately after the Fukushima Dai-ichi accident.



- ✓ Interactive map are available with

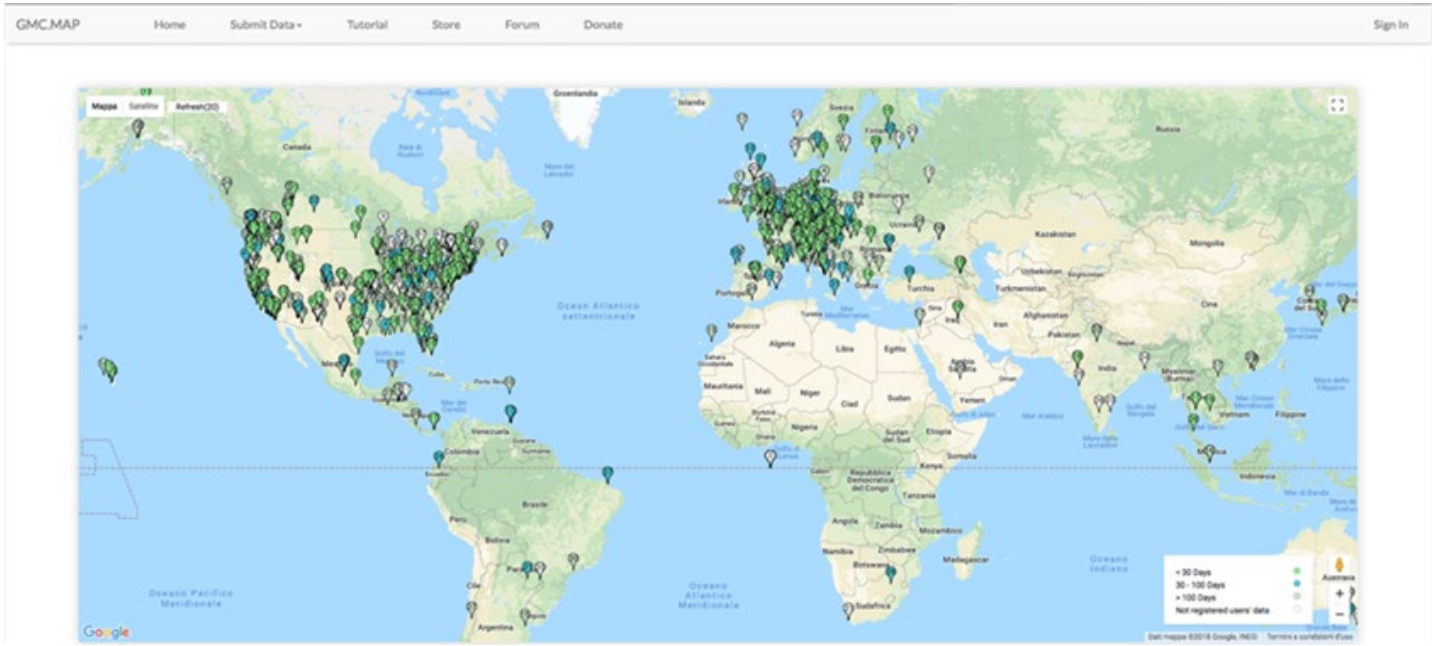
the different dose rate of the measurement point.

- ✓ The colour-code is related to the intensity of dose rate:
  - black correspond to the lower possible value (almost 0.03µSv/h)
  - yellow correspond to the higher possible value (almost 10 µSv/h).

This network is based on the belief that that having more freely available open data is better for everyone.

Overview on non-governmental networks in Europe

GMC Map is sponsored by GQ Electronics LLC and it is free and open protocol map.



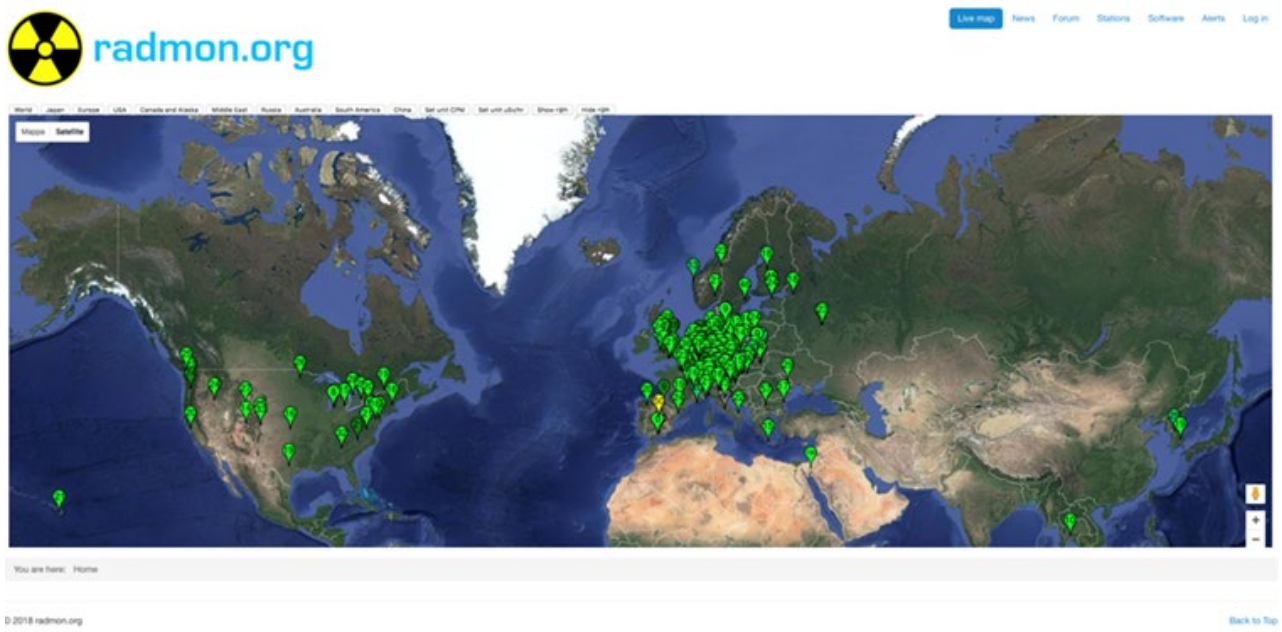
✓ Interactive maps are available with detailed information for users:

- Name of the station;
- CPM, ACPM, Sv/h measurement value;
- Tube models;
- Measurement station position coordinate.

✓ The pointers are characterized:

- by a color, that denote the last connection of the measurement station with the network database; and
- by a number that tell the last measurement, in CPS, registered by stations.

Overview on non-governmental networks in Europe

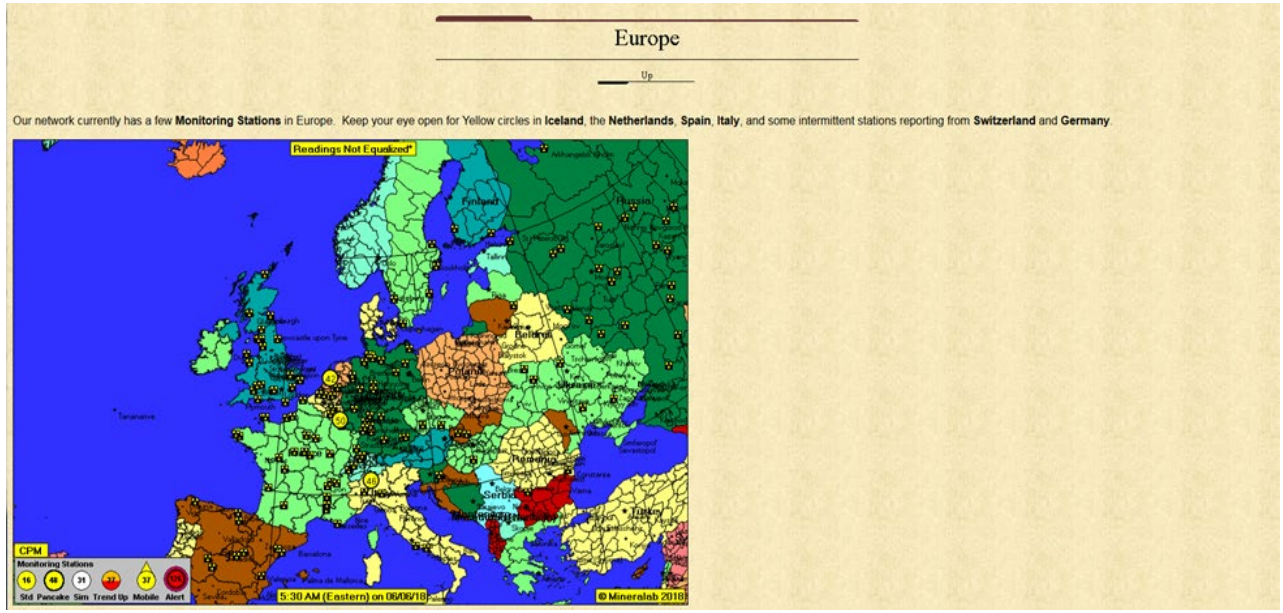


Interactive maps give detailed information to users:

- Name of the station;
- CPM, µSv/h measurement value;
- CPM to µSv/h Conversion factor;
- Warning level and Alert level;
- Detector model and Tube model;
- Coordinate of the position of the measurement station;
- Historical data with the temporal progress of the measures (CPM)(6 hours).

Overview on non-governmental networks in Europe

Radation network is operated by Mineralab. Radiation network website has different maps in different website pages (USA, Alaska and Hawaii, Japan, Europe, Australia, South America).



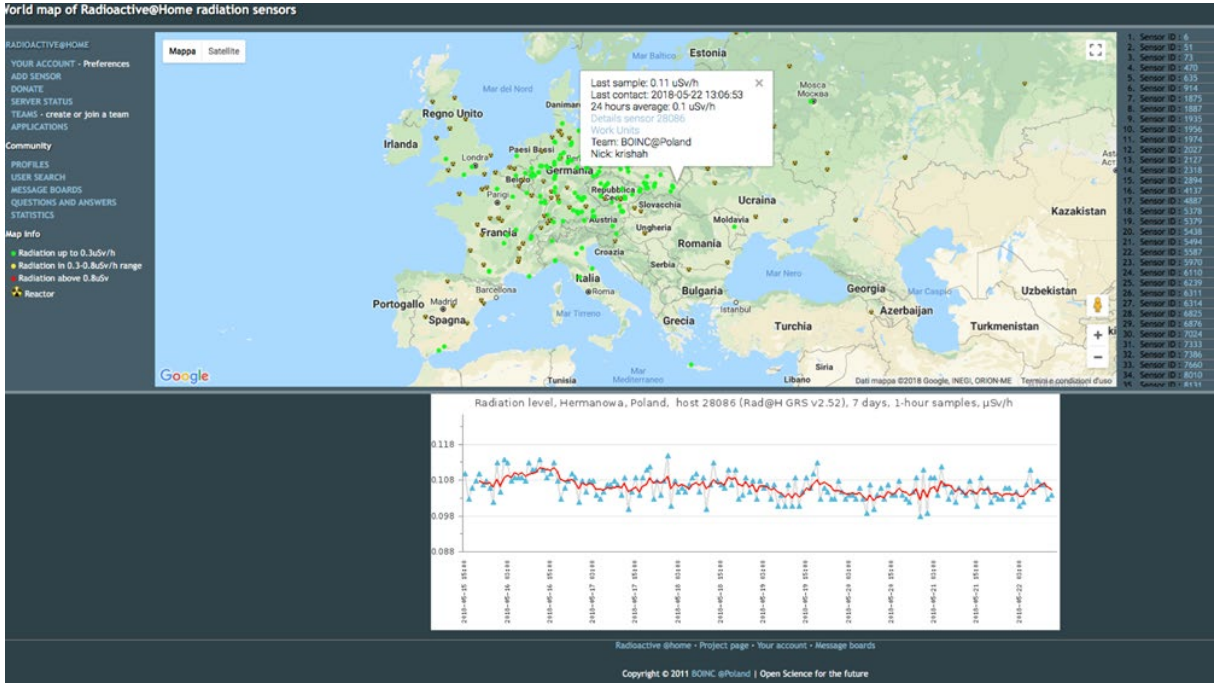
✓ The time and date stamp at the bottom center of the map, indicate how recently the map has been updated.

✓ A legend explains the symbols on the maps:

- different symbols for different instruments and for mobile station;
- the colours orange/red represent increasing values
- there is also a symbol for the Alarm that is set when a measurement exceeds 100 CPM, or 2.5 times a Station's baseline readings

Overview on non-governmental networks in Europe

Radioactive@home is a polish science project and its main goal of the project is to create free and constantly updated map of radiation available for all people, by gathering information about gamma radiation using sensors connected to computers of volunteers willing to participate in the project.

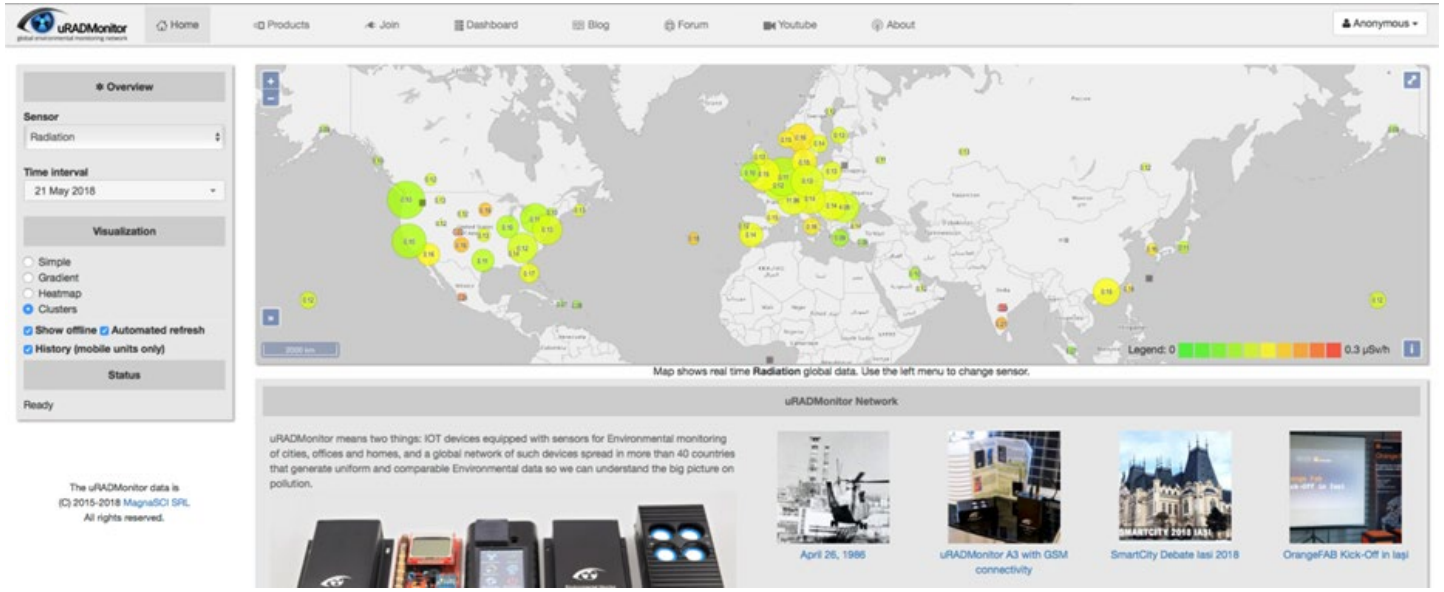


The information gives to the users are:

- Last sample in µSv/h;
- Last connection of the device with the network database;
- 24 hours average in µSv/h;
- Sensor and detector information;
- Detector model and Tube model;
- Team and owner of the detector;
- Historical data with the temporal progress of the measures (CPM)(6 days).

Overview on non-governmental networks in Europe

uRad: is a project built for the community, it is operated by MagnaSCI to build a tool to serve the public.



✓ The information gives to the users are:

- The name of the station, the country flag, the city and the coordinate of the measurement station.
- Detector and sensor model;
- Station status (online or offline)
- Historical data with the temporal progress of the measures (µSv/h)

✓ The value shown in each circle represents the average dose rate values of the measurement stations contained within the cluster.

Overview on non-governmental networks in Europe

Network	Data submission	Raw/ displayed data	$\dot{H}^*(10)$	Additional Information
Safecast with mobile devices	Automatic* and manual	CPM / µSv/h	Yes	<0,4µSv/h; 0,4-2µSv/h; >2µSv/h (blue – red- yellow)
GMC map with fixed stations	Automatic and manual	CPM or ACPM /CPM or µSv/h	Sometimes	Colours of the stations is related to data updating time
Radmon with fixed stations	Automatic and manual	CPM / CPM or µSv/h	Sometimes	Warning level: 50 CPM Alert level 100 CPM
Radiation Network with fixed stations	Automatic	CPM/ CPM	No	Alert level: 3 consecutive minutes of lesser of 100 CPM or 2.5 times a Station's baseline
Radioactive@Home with fixed stations	Automatic	CPM / µSv/h	Yes	<0,3µSv/h; 0,3-0,8µSv/h; >0,8µSv/h (green; yellow; red)
uRad Monitor with fixed stations	Automatic	CPM / µSv/h	Yes	<0,12µSv/h; 0,12-0,21Sv/h; >0,21µSv/h (green; yellow; red)

*in Japan

Overview on non-governmental networks in Europe

Example of MINN	Supplier	Networks
uRAD Monitor Model A	Magna SCI	uRad Monitor
GMC-600	GQ Electronics	GMC map
bGaiger Nano	Safecast	Safecast
Radalert 100	International Medcom	Radiation Network/Safecast
GMC-320 Plus	GQ Electronics	GMC map / Radmon
GMC-500 Plus	GQ Electronics	GMC map / Radmon
uRAD Monitor model KIT1	Magna SCI	uRad Monitor
Monitor 4 Geiger Count KIT	S.E. International Inc.	Radiation Network
GMC-300 Plus	GQ Electronics	GMC map
RADEX 1212	Quarta-RAD Inc.	GMC map/ RadexRead Radiation Mapping
PMR 7000	Mazur	Radiation Network
Monitor 200	S.E. International Inc.	Radiation Network
uRAD Monitor Model D	Magna SCI	uRad Monitor
MyGeiger ver.3 PRO DIY	RH Electronics	Radmon
Inspector Alert	International Medcom	Radiation Network
Rad 100	International Medcom	Radiation Network/Safecast

Metrological investigation of MINNs data

Investigation of the feasibility of using dose collected from non – governmental networks for official preparedness purposes:

1. Metrological measuring campaigns: the performance of MINN were investigated by using reference facilities for dosimetry of PTB.

determination of inherent background	**response to secondary cosmic radiation**	**sensitivity to small variation of $\dot{H}^*(10)$**	**response to different environmental conditions**

2. Metrological measuring campaigns: the performance of MINN were investigated by using reference facilities for dosimetry of PTB, ENEA, VINS and NPL.

energy dependence: irradiations at 8 radiation qualities in energy range from 60 keV to 1250 keV	**linearity of response: irradiations at different dose rates ranging from 300nSv/h to 100 μSv/h**

Metrological investigation of MINNs data

- Each partner selected 4 different detector models from those generally used for non-governmental networks and 4 detectors were purchased per type to properly verify the working of devices.

Selection criteria used by ENEA for choosing NIMMs:

- Assembled Geiger detectors (user friendly)
- Price range for each detector: 100 – 400 € (average price on 16 devices 280€)
- Internal memory for data recording
- Data download by USB cable or Bluetooth connection and software available on line

Detectors for users with non-specialist technical skills

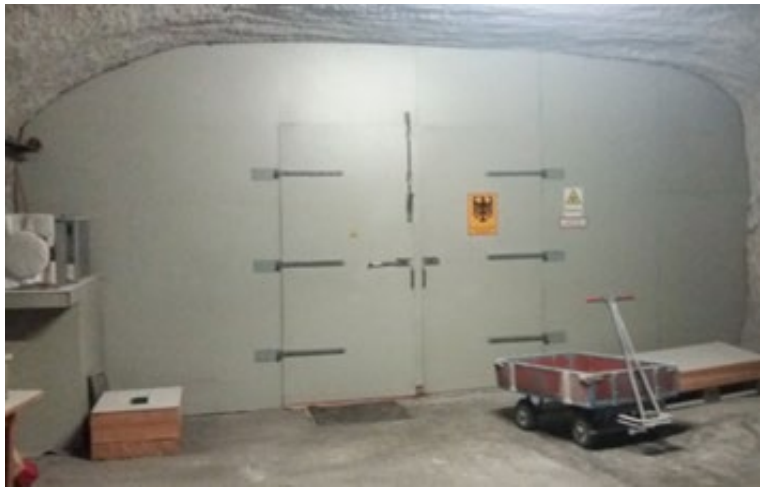
Metrological investigation of MINNs data

- According to the Publication 103 of ICRP one of the operational quantity used for area monitoring is the ambient dose equivalent H*(10) and its unit of measurement is sievert (Sv). The instruments for radiation monitoring should be calibrated in terms of these quantities.

	Measurement Unit	CF[1]	t_R[1]	t_{int}[2]
MINN n°1	μSv/h	-	1 min	10 sec
MINN n°2	CPM	1CPM=0,009346μSv/h	1 min	30 sec
MINN n°3	CPM	1CPM=0,022222μSv/h	1 min	20 sec
MINN n°4	μSv/h	-	1 min	Data not available

1 – CF: Convertion Factor declared by the manufacturer.
2 – t_R: Time period for data recording
3 – t_{int}: Integration time for single acquisition

Metrological investigation of MINNs data



Determination of inherent background

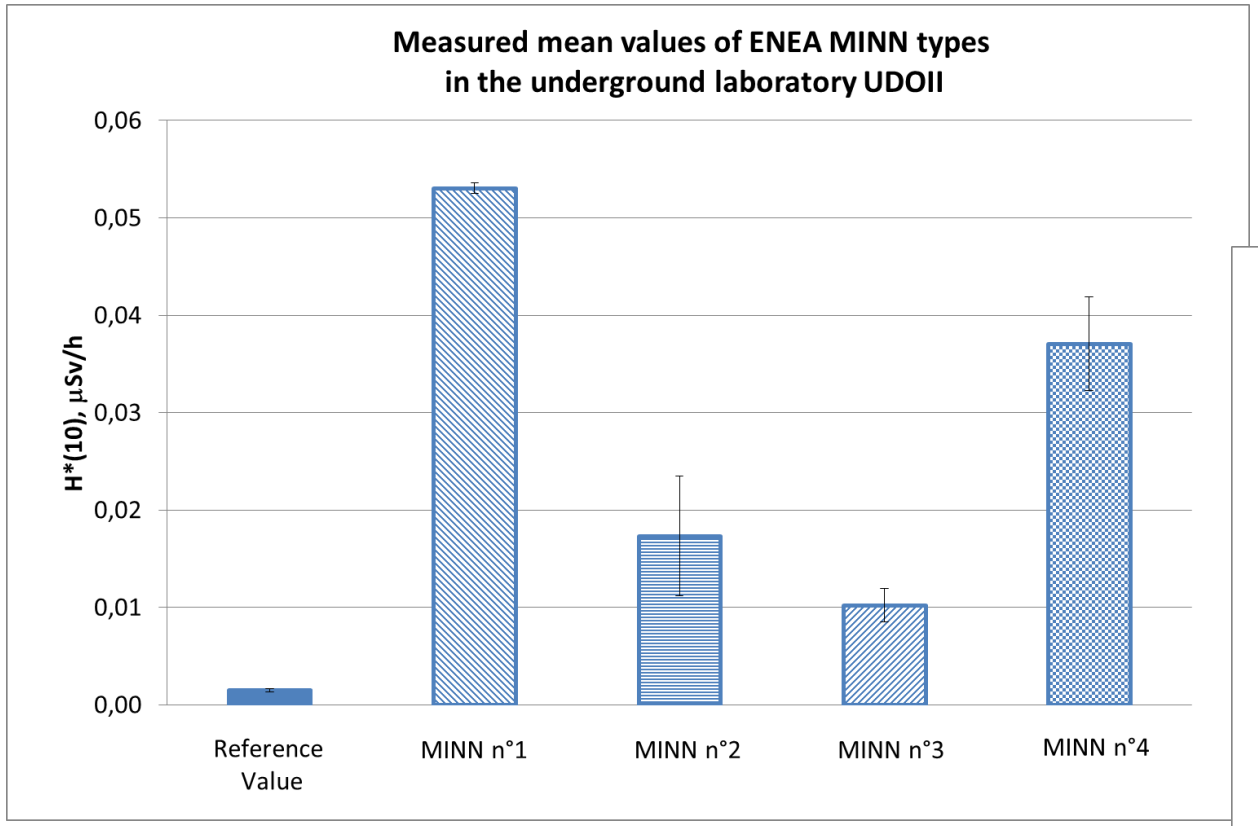
Measurements in the absence of radiation fields:

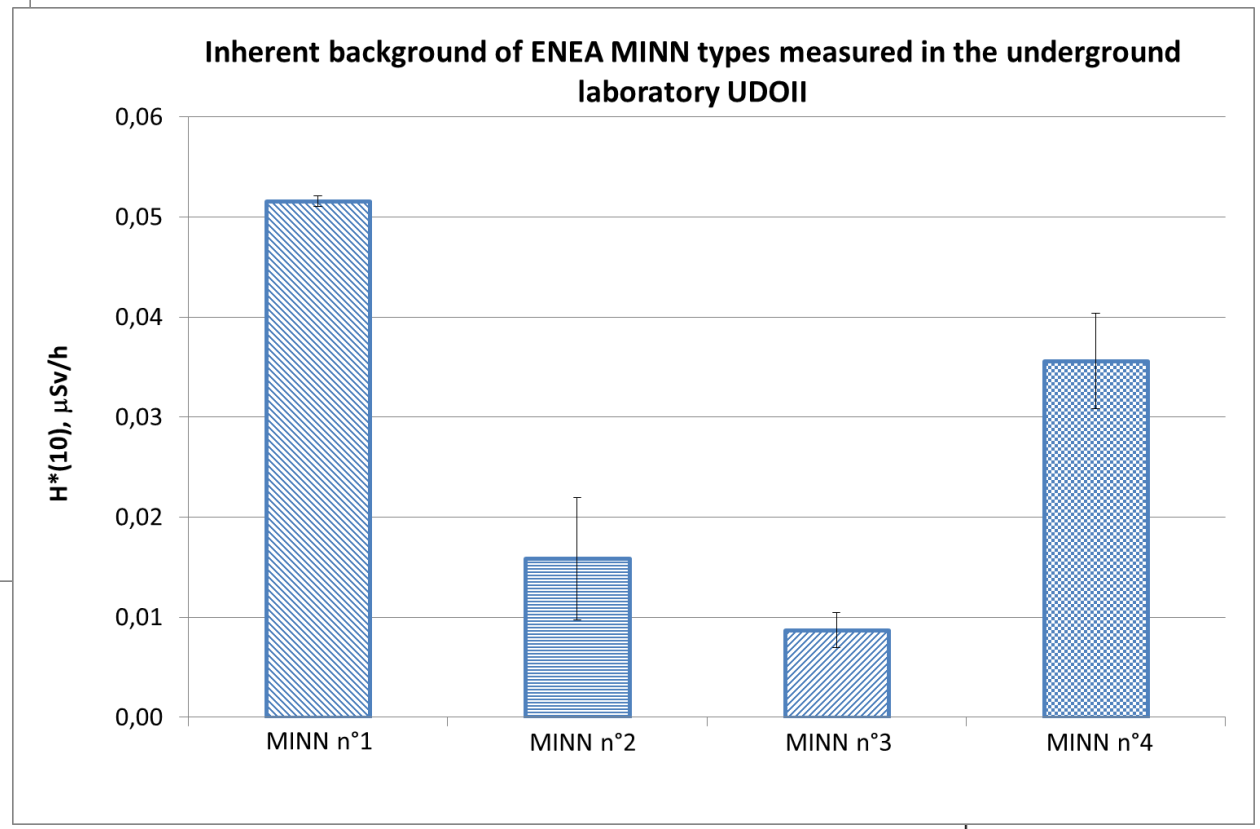
- The PTB UDOII Laboratory is located at around 430 m deep in a salt mine.
- The cosmic radiation **background** is very small compared to surface values, while the contribution of primordial radionuclides and in particular of radon gas and its progeny can be considered negligible.

Very low background radiation: 1.4 ± 0.2 nSv/h.

The measurement campaign was conducted for 4 hours in order to guarantee good statistics of data acquisition.

Metrological investigation of MINNs data



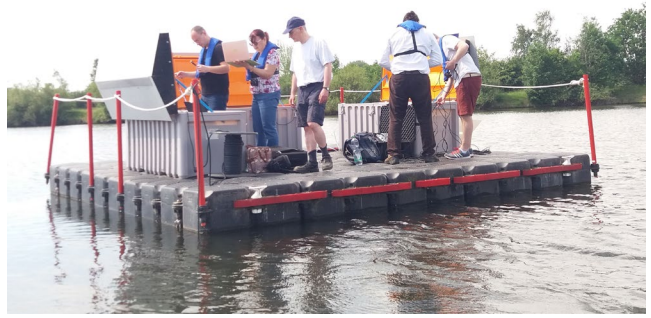


Metrological investigation of MINNs data

Response to secondary cosmic radiation

Measurements performed in an almost pure secondary cosmic radiation field:

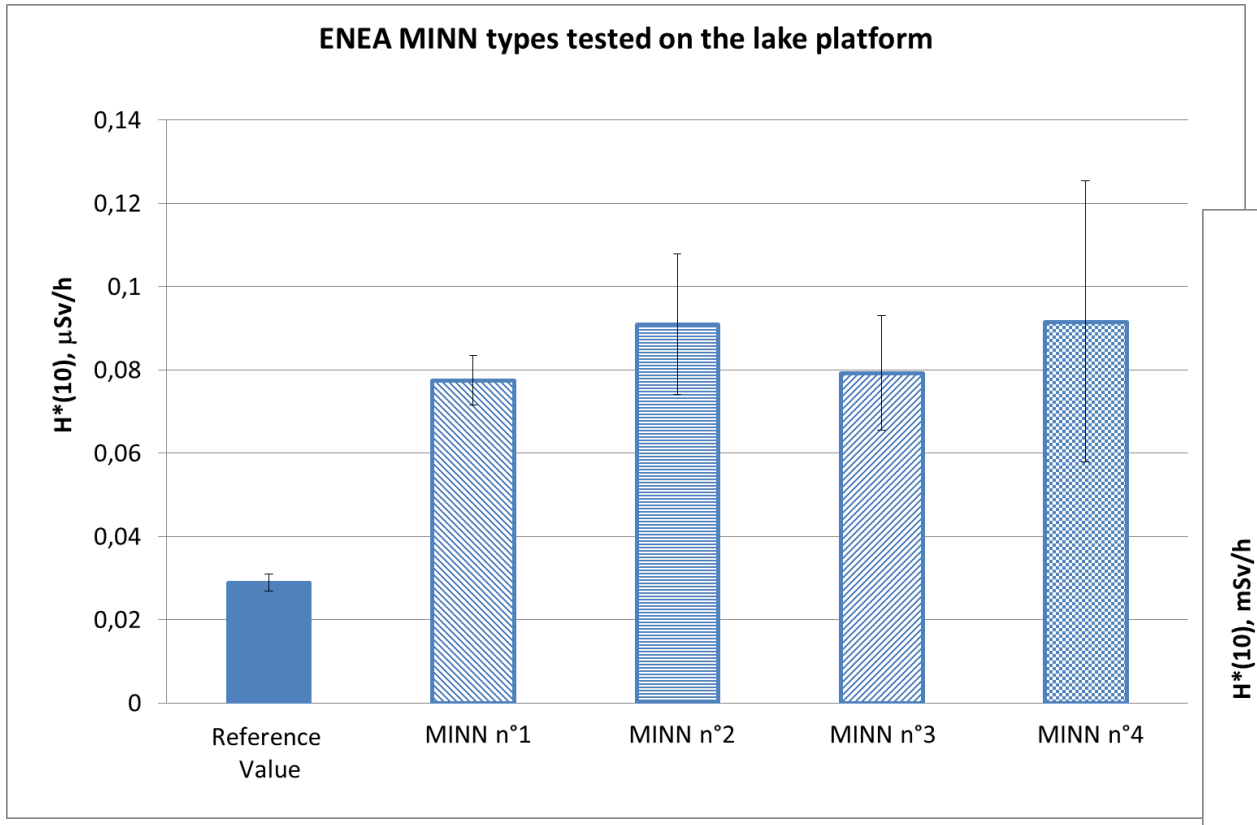
- The PTB floating platform constructed from material of low radioactivity, located at around 100m from the cost and at the bottom of the Brunswick lake (Germany) that is 3 m deep.
- The cosmic radiation is negligible (around 1nSv/h).

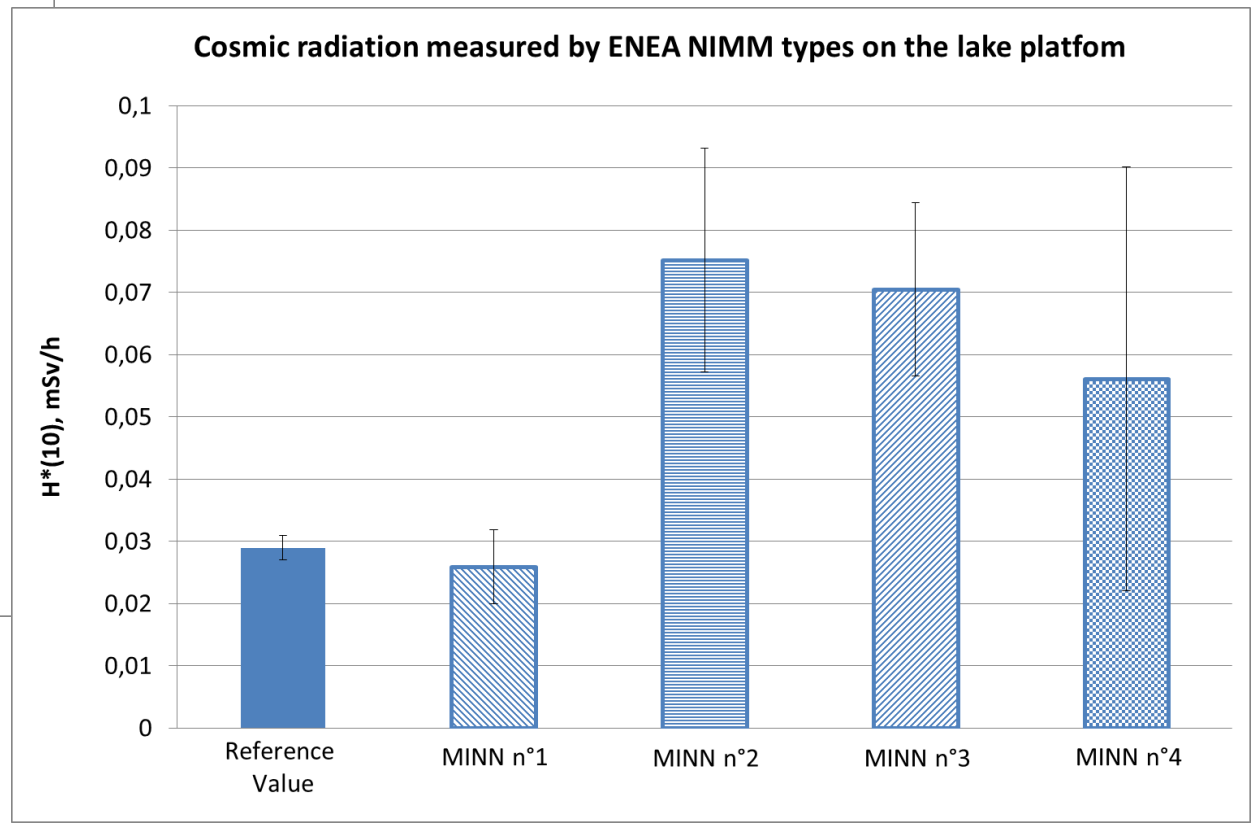


Reference level of background: 0.029 ± 0.002 μSv/h.

The measurement campaign was conducted for 1.5 hours.

Metrological investigation of MINNs data



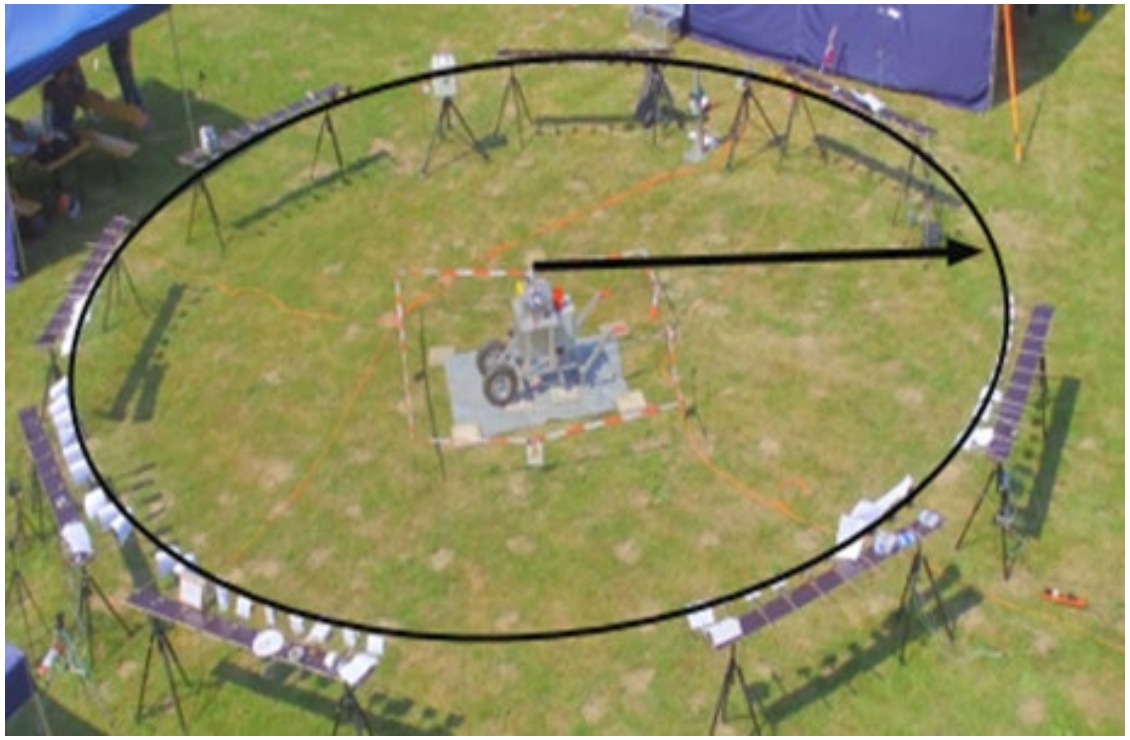


Metrological investigation of MINNs data

Sensitivity to small variation of $\dot{H}^*(10)$

The plume simulation emulates a passing of a radioactive plume across the site.

- The location for the plume simulation test is an open-air meadow on the PTB.
- The measurement campaign was conducted for 4.5 hours.

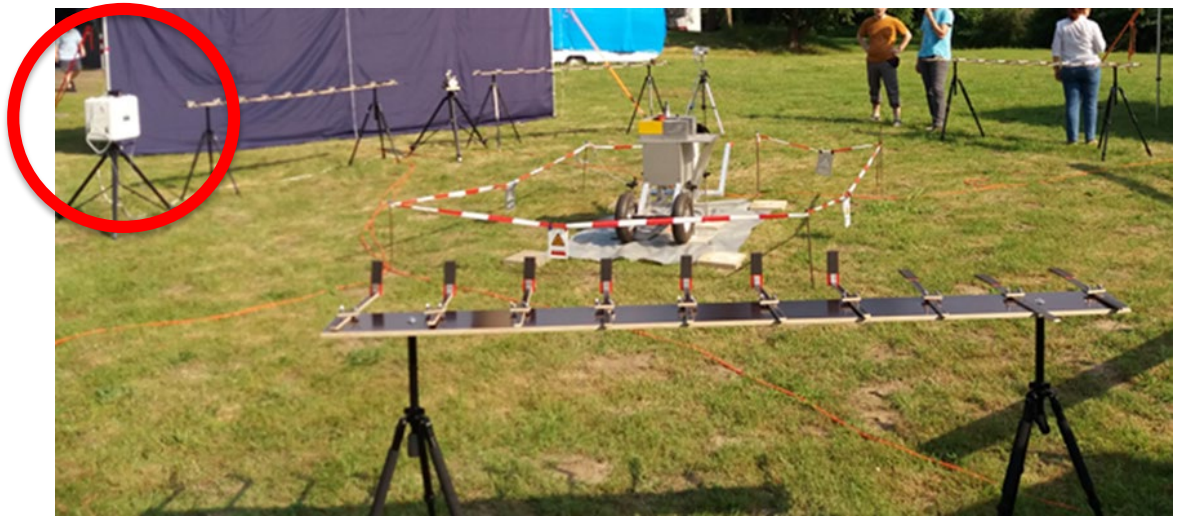


All MINNs were positioned 20 cm apart from each other, such that the geometrical middle of their Geiger tubes have 1 m height above the ground and 5 m to the source.

Metrological investigation of MINNs data

Sensitivity to small variation of $\dot{H}^*(10)$

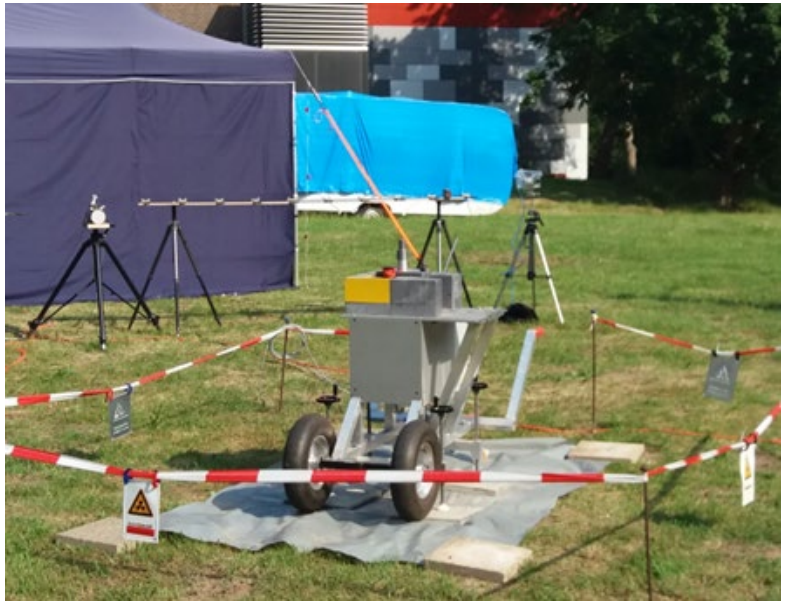
A secondary standard Reuter Stokes ionization chamber (type RS-131) was installed on the circle as the reference instrument and operated during the test to provide reference dose rates.



It was calibrated in the underground laboratory UDOII and provides reference values traceable to the PTB primary standards.

Reference level of background: 0.0758 ± 0.0046 μSv/h.

Metrological investigation of MINNs data



Sensitivity to small variation of $\dot{H}^*(10)$

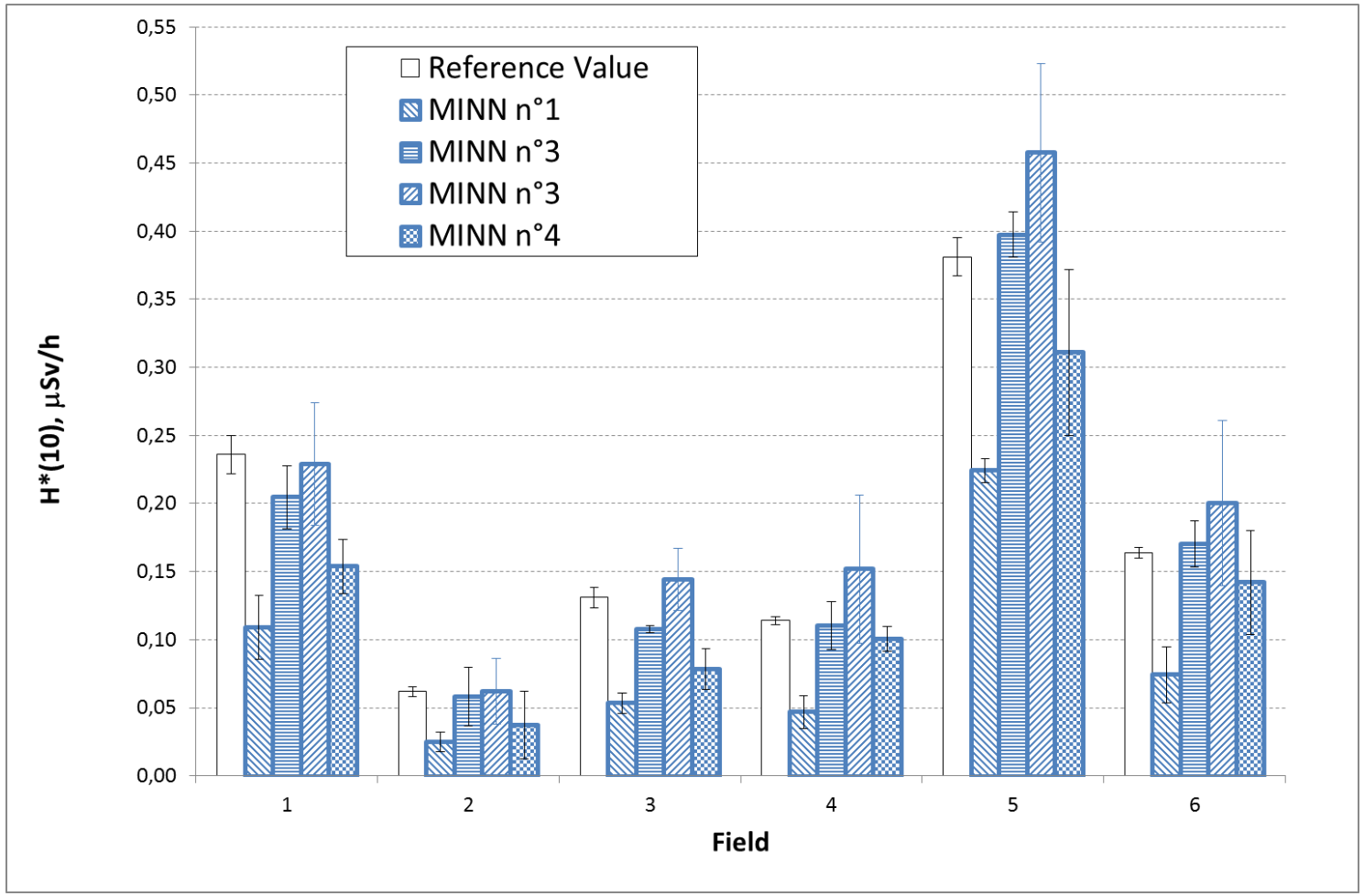
The employed homemade machine is able to incorporate up to 4 different point-like γ sources.

The irradiator is equipped with a variable shielding system inside which the sources can move and change the dose rate. The timeline was taken from the protocol of the plume machine written automatically by the control software.

Radiation field	Source	$\dot{H}^*(10)$– (μSv/h)
1	^{137}Cs	0.236±0.014
2	^{137}Cs	0.062±0.004
3	^{137}Cs	0.131±0.008
4	^{60}Co	0.114±0.003
5	^{226}Ra	0.381±0.014
6	^{60}Co	0.164±0.004

Metrological investigation of MINNs data

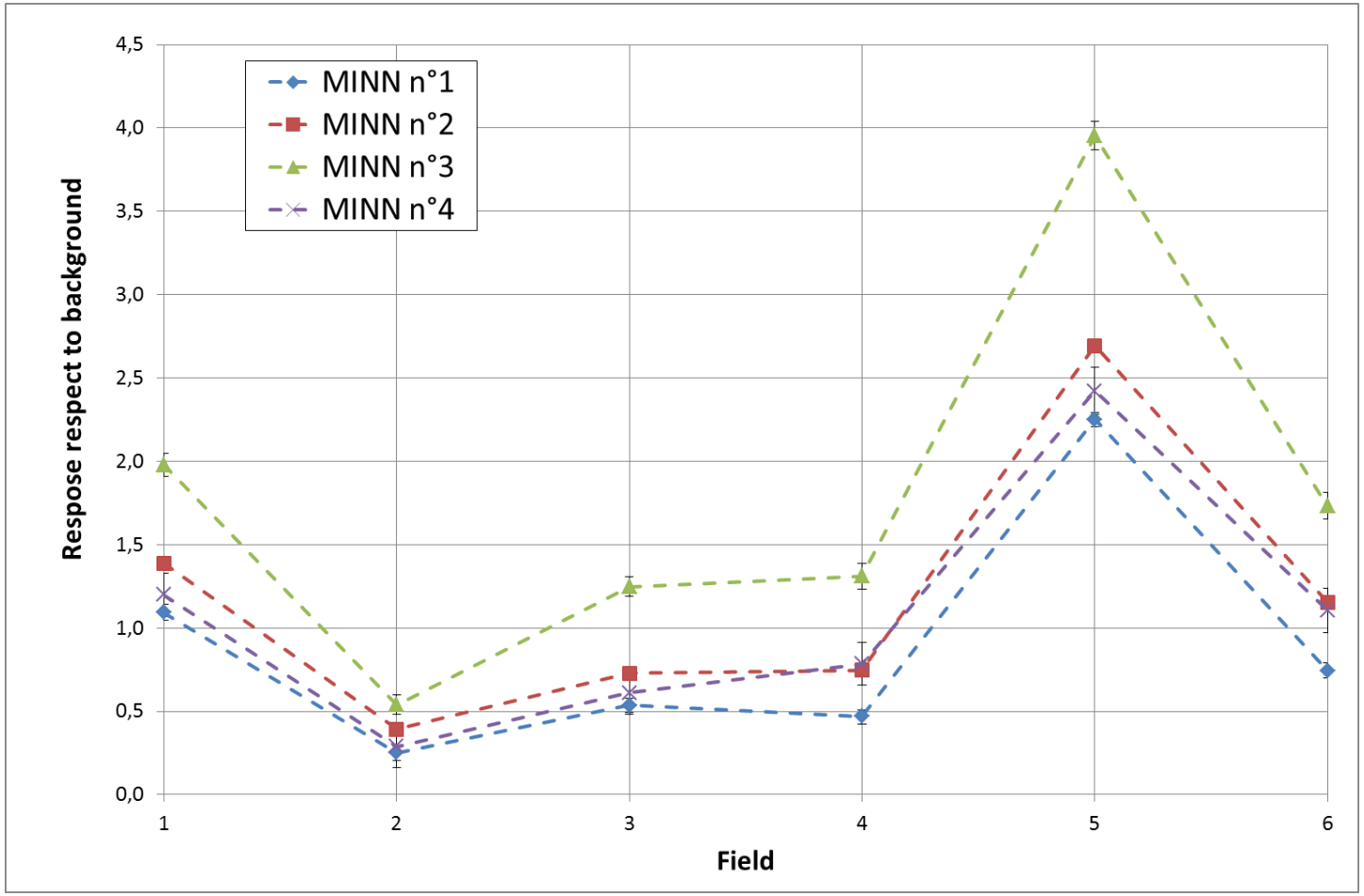
The final absolute results(*) for ENEA MINNs compared with the reference value for the corresponding.



(*) Starting from the raw data, after subtraction of the background measured on site, the values were averaged within the MINN type.

Metrological investigation of MINNs data

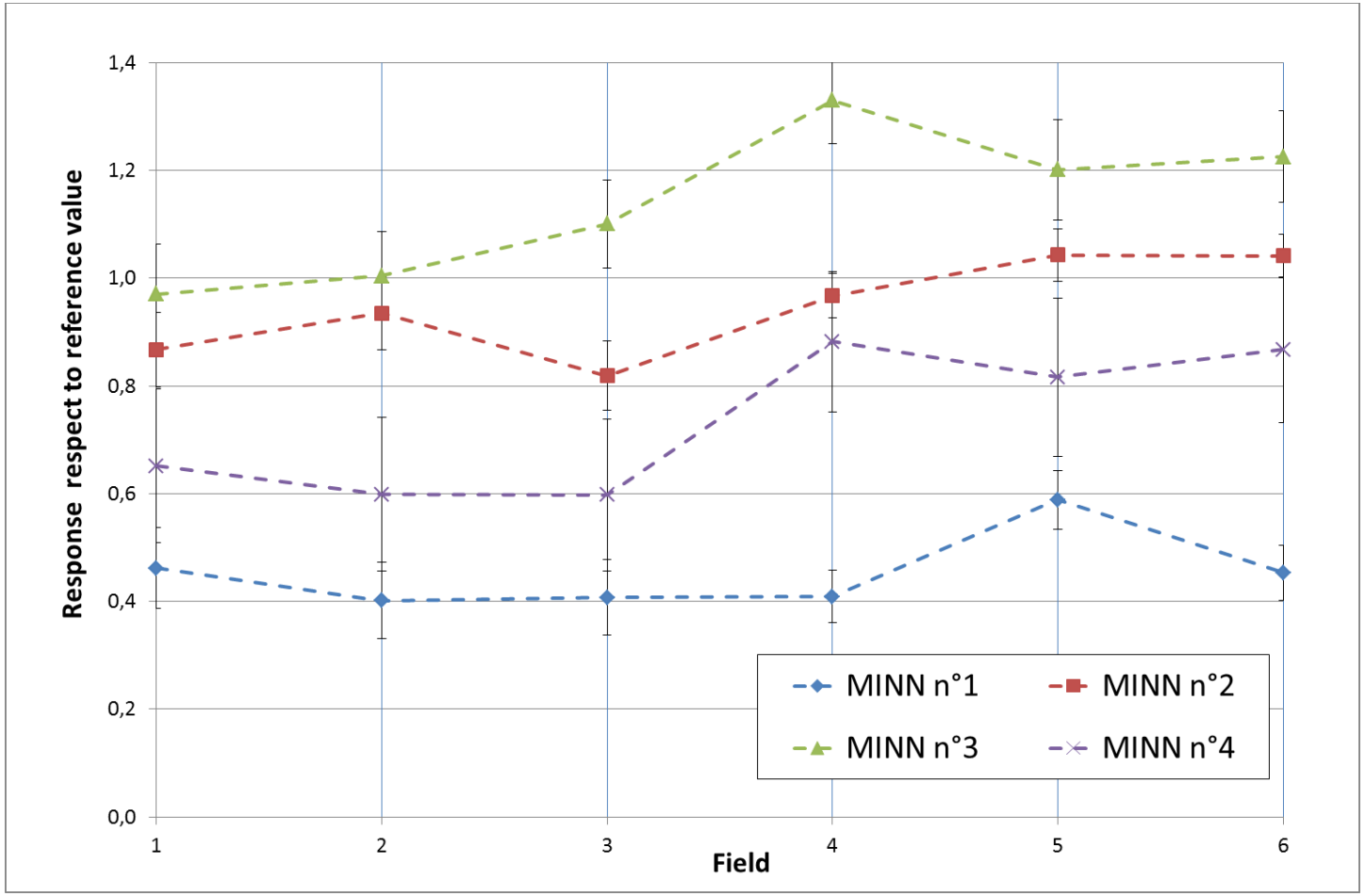
Absolute increase of the dose rate* due to artificial gamma source normalized by the background in absence of the source



(*) Starting from the raw data, after subtraction of the background measured on site by each device, the values were averaged within the MINN type.

Metrological investigation of MINNs data

Absolute increase of the dose rate* due to artificial gamma source normalized by the corresponding reference dose rate at the given photon field



(*) Starting from the raw data, after subtraction of the background measured on site, the values were averaged within the MINN type.

Conclusions - I

- When the instrument response is expressed in counting rate (count per minutes, CPM; counts per second, cps), it should be converted to ambient dose equivalent rate $\dot{H}^*(10)$ $(\mu\mathrm{Sv/h})$.
- The limitations of data displayed in non-governmental network sites are strictly related to detector characteristics and station location.
- Currently there are not clear information for the public about correct interpretation of the variability of the data.
- The vulnerability of these web sites has not yet investigated.

Conclusions - II

- Preliminary results of the PTB intercomparison (June 2019 – Germany) were presented for 4 types of MINNs:
  - the study of inherent background;
  - the response to cosmic radiation;
  - the sensitivity to small variation of $\dot{H}^*(10)$.

- The four types of MINN analyzed are functional for carrying out measurements in the context of non-governmental monitoring networks, allowing the detection of dose increases with respect to the reference background of ~60nSv /h (corresponding to an increment of dose from external radiation of ~0.5mSv / year).

Conclusions - III

- The strength of the non-governmental networks web sites is the ability to disseminate a citizen participation and science culture. These communication channels should be supported from “institutional science” and the active involvement of the public should be encouraged.

- A training support for operators and users of non-governmental networks web sites is desirable to disseminate an accurate citizen-science on the basis of the results of the metrological investigation defined by WP3 of Preparedness project

PTB
Messen ▪ Forschen ▪ Wissen

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

European Commission

Thank you

for attention!

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NPL
National Physical Laboratory

Vinca Institute of Nuclear Sciences

PREPAREDNESS

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

http://www.preparedness-empir.eu/

EMPIR

EURAMET

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