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- Social and legal issues of citizen radiation measurements

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Abstract

Citizen-led radiation measurements play an increasingly important role in environmental monitoring, but they also raise important social and legal questions about how such data can be used by official authorities and institutions. On one hand, measurements provided by the public can enhance transparency, empower residents, and help detect anomalies that official monitoring might miss. On the other hand, these data often vary in accuracy, calibration, and methodology, which can create legal difficulties when authorities consider them for regulatory decisions, public warnings, or emergency responses.

Socially, the use of citizen data can strengthen trust if institutions acknowledge and integrate community findings appropriately. Legally, authorities must navigate privacy rules, the validity of non-certified instruments, liability for acting on public measurements, and standards for incorporating third-party data into official assessments. Overall, the relationship is a balance between public empowerment and the need for scientifically validated, legally defensible information.

The report summarizes social and legal aspects of citizen radiation measurements in Czechia, Slovakia and Poland. The first part of the deliverable is devoted to description of the baseline status in each country - nuclear energy installations, the impact of the Chernobyl nuclear accident and the less old, although geographically distant, accident in Fukushima in 2011. The most significant factor that negatively influenced the public perception of radiation and radioactivity was the nuclear accident in Chornobyl in 1986. In all three countries, as satellite states of the Soviet Union, the published information was restricted and censored with clear effort to downplay the severity of the accident. The possibilities for citizen measurements in the 1980s were very limited. The impetus for the emergence of radiation measurement by citizens was the Fukushima accident in 2011. We review the most important projects and collaborations that emerged after the Fukushima accident in the field of citizen radiation measurements from small do-it-yourself projects to large ones, namely SAFECAST, which brought certain standards to this field and built everything on transparency and open data.

The next part of the document describes the legal framework in case of a radiation emergency and possible implementation of the citizen radiation measurements including the main limitations related to data quality and data quality control. Finally, we summarize conclusions and recommendations of citizen radiation measurements integration into the broader radiation protection framework. The CITISTRA project demonstrates that citizen science can play a constructive role in radiation protection, provided that its limitations are acknowledged and its contributions are embedded within a robust legal and institutional framework.

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List of abbreviations

AČR	Czech Army
BSS	Basic Safety Standard
CSV	Comma-separated values, plain text data format
CZ	Czechia, Czech Republic
ČHMÚ	Czech Hydrometeorological Institute, Český hydrometeorologický ústav
DIY	Do it Yourself
EANR	European Atlas of Natural Radiation
ECURIE	European Community Urgent Radiological Information Exchange system
EU	European Union
EURDEP	EUropean Radiological Data Exchange Platform
EWN	Early Warning Network
GM tube	Geiger-Müller tube
HWGCR	Heavy Water Moderated Gas Cooled (nuclear) Reactor
HZS	Fire and Rescue Service (in Czechia)
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units and Measurements
IMGW	Institute of Meteorology and Water Management, Instytut Meteorologii i Gospodarki Wodnej (Poland)
MCU	microcontroller unit - compact, single-chip computer
MEXT	Nuclear Safety Division of the Ministry of Education, Culture, Sports, Science and Technology (Japan)
MonRaS	monitoring of the radiation situation (Czechia)
NCBJ	National Centre for Nuclear Research, Narodowe Centrum Badań Jądrowych (Poland)
NPP	Nuclear Power Plant
NRHP	National Radiation Emergency Plan (in Czechia)
PAA	National Atomic Energy Agency, Poland)
PHA SR	Public Health Authority of the Slovak Republic
PL	Poland
PMS	Permanent Monitoring Station
PWR	Pressurized Water (nuclear) Reactor
SHMÚ	Slovak Hydrometeorological Institute, Slovenský hydrometeorologický ústav
SMR	Small Modular (nuclear) Reactor
SPEEDI	System for Prediction of Environment Emergency Dose Information (Japan)
SR	Slovakia, Slovak Republic
SÚJB	State Office for Nuclear Safety (Czechia)
SÚRO	National Radiation Protection Institute, Státní ústav radiační ochrany (Czechia)
WHO	World Health Organization

1 Introduction

All three countries participating in the CITISTRA project, Czechia, Slovakia and Poland, are members of the European Union and as such must comply with EU regulations and EU legislation regarding the peaceful use of nuclear energy and implementing guidelines and recommendation from organisations like the International Atomic Energy Agency (IAEA), the World Health Organization (WHO) and the International Commission on Radiological Protection (ICRP).

All three countries are also members of the North Atlantic Treaty Organization (NATO), so the response to a radiation event in the event of armed conflict should also follow defined international guidelines.

Although much of the legislation and regulations regarding response to a radiological event are based on the aforementioned international guidelines and recommendations, the Chornobyl accident in 1986 had a major influence on developments in all three countries. Therefore, the impacts of the Chornobyl accident on these countries, the resulting measures, the method of response (media, communication), etc., are addressed in chapter 2.1.

1.1 Current status of nuclear power installations in partner countries

The situation regarding radiation protection and the resulting emergency preparedness and response is largely influenced by the use of nuclear energy and nuclear installations in individual countries. Both Czechia and Slovakia operate nuclear power plants, while Poland is preparing to build its first nuclear power plant in the near future and is also considering investments into several small modular reactors (SMRs). Both Czechia and Poland also have one or more research nuclear reactors in operation.

Czechia operates two nuclear power plants: Temelín and Dukovany - total of 6 reactors in operation, 1 more planned [1][2][3]. Both power plants are operated by ČEZ Group (In Czech: 'Skupina ČEZ', České Energetické Závody) which is also operating non-nuclear power plants in the country. Its majority shareholder is the Czech government.

Table 1: Nuclear power reactors in Czechia (Source: IAEA PRIS, https://pris.iaea.org/PRIS/)

Name	Type	Status	Location	Reference Unit Power [MW]	Gross Electrical Capacity [MW]	First Grid Connection
DUKOVANY-1	PWR	Operational	Dukovany	468	500	1985-02-24
DUKOVANY-2	PWR	Operational	Dukovany	471	500	1986-01-30
DUKOVANY-3	PWR	Operational	Dukovany	468	500	1986-11-14
DUKOVANY-4	PWR	Operational	Dukovany	471	500	1987-06-11
TEMELIN-1	PWR	Operational	Temelín	1027	1082	2000-12-21
TEMELIN-2	PWR	Operational	Temelín	1029	1082	2002-12-29

In addition, there are several research reactors in Prague and Husinec, Řež. The VR-1 and VR-2 reactors are located at the Czech Technical University in Prague. Research Centre

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Řež s.r.o. company is operating another two research reactors - LR-0 and LVR-15 in Husinec-Řež about twelve kilometers north of the center of Prague city.

Slovakia also operates two nuclear power plants: Bohunice and Mochovce - 5 reactors in total, one more is under construction. Both power plants are operated by the company Slovenské elektrárne, a.s. Slovenské elektrárne, a.s., which currently has two shareholders. The majority shareholder is Slovak Power Holding B.V. (SPH), which owns 66%. The Czech energy group Energetický a průmyslový holding, a.s. (EPH) owns 100% of the share capital in SPH. The acquisition from the Italian company Enel Produzione S.p.A. was completed in May 2025. The Slovak Republic has a 34% stake in the power plants.

Table 2: Nuclear power reactors in Slovakia (Source: IAEA PRIS, https://pris.iaea.org/PRIS/)

Name	Type	Status	Location	Reference Unit Power [MW]	Gross Electrical Capacity [MW]	First Grid Connection
BOHUNICE A1	HWGCR	Permanent Shutdown	Jaslovské Bohunice	93	143	1972-12-25
BOHUNICE-1	PWR	Permanent Shutdown	Jaslovské Bohunice	408	440	1978-12-17
BOHUNICE-2	PWR	Permanent Shutdown	Jaslovské Bohunice	408	440	1980-03-26
BOHUNICE-3	PWR	Operational	Jaslovské Bohunice	466	500	1984-08-20
BOHUNICE-4	PWR	Operational	Jaslovské Bohunice	466	500	1985-08-09
MOCHOVCE-1	PWR	Operational	Levice	467	500	1998-07-04
MOCHOVCE-2	PWR	Operational	Levice	469	500	1999-12-20
MOCHOVCE-3	PWR	Operational	Levice	434	471	2023-01-31
MOCHOVCE-4	PWR	Under Construction	Levice	440	471	

Poland does not yet have any nuclear power plants. There are plans to build a nuclear power plant in the north of the country at the Lubiatowo-Kopalino site - the start of construction is intended for 2026 and commissioning for 2033. Three AP1000 reactors by Westinghouse Electric, each with an electric power of 1250 MW are planned. Furthermore, 6 other locations selected for the construction of power plants based on GE Hitachi Nuclear Energy's BWRX-300 small modular reactor were approved - 24 BWRX-300 reactors in total - to be operated by the ORLEN Group company [4][5].

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Figure 1. Nuclear reactors in Czechia, Slovakia and Poland

Poland also operates one research reactor - Maria reactor - in Narodowe Centrum Badań Jądrowych (in English: National Centre for Nuclear Research, NCBJ) Świerk-Otwock.

1.2 Official radiation monitoring networks

All three countries operate stationary early warning networks (EWN) with real-time gamma radiation detectors. These networks are connected to the early warning systems of the individual countries and data is also provided to the EUropean Radiological Data Exchange Platform (EURDEP). This data exchange is regulated by both the Council Decision 87/600 (ECURIE Arrangements) and the Recommendation 2000/473/ Euratom.

However, EURDEP is not a rapid alert system. The early notification of a radiological accident or emergency is carried out via the European Community Urgent Radiological Information Exchange system (ECURIE) operated by the European Commission on a 24/7 basis.

Czechia

Monitoring of the radiation situation in the Czech Republic is ensured primarily through the nationwide Radiation Monitoring Network. The State Office for Nuclear Safety (SÚJB) is responsible for managing the network's activities. In addition to SÚJB, the National Radiation Protection Institute (SÚRO), and the operators of nuclear power plants, the Ministry

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of Finance, the Ministry of Defence, the Ministry of the Interior, the Ministry of Agriculture, and the Ministry of the Environment are currently involved in the actual monitoring.

The basis of the network are online dose rate measurement stations located at the sites of SÚJB, SÚRO, meteorological stations (ČHMÚ), sites of the Fire Department (HZS) and the Czech Army (AČR). In the vicinity of nuclear power plants, the network is supplemented with additional monitoring stations. There are also sites with advanced monitoring methods (aerosol sampling, spectrometry, etc.).

Data from online dose rate stations are available on the SÚJB website in the online application MonRas and are also provided to the EURDEP platform. As of 27 November 2025, 64 stations measuring online gamma dose rates were available for Czechia.

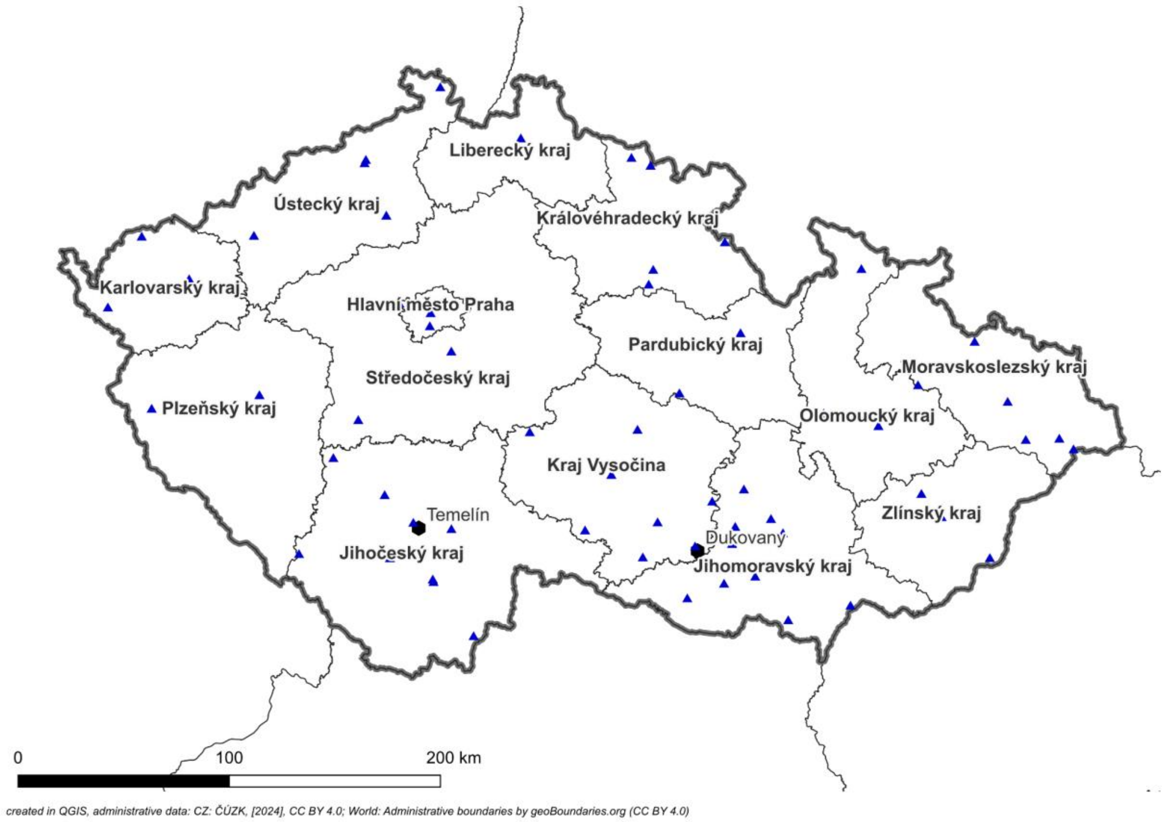

Figure 2. EWN stations (blue triangles) in Czechia

The high number of EWN stations in regions South Bohemian (Jihočeský kraj), South Moravian (Jihomoravský kraj) and Vysočina (Kraj Vysočina) correlates with the location of the two Czech nuclear power plants - Temelín and Dukovany.

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Table 3: EWN stations in Czechia by region

Region (kraj)	Capital city	Area (km^2)	EWN stations
Prague (Praha)		496	3
Central Bohemian (Středočeský kraj)	Prague (Praha)	10,929	3
South Bohemian (Jihočeský kraj)	České Budějovice	10,058	9
Plzeň (Plzeňský kraj)	Plzeň	7,649	2
Karlovy Vary (Karlovarský kraj)	Karlovy Vary	3,31	3
Ústí nad Labem (Ústecký kraj)	Ústí nad Labem	5,339	5
Liberec (Liberecký kraj)	Liberec	3,163	1
Hradec Králové (Královéhradecký kraj)	Hradec Králové	4,759	5
Pardubice (Pardubický kraj)	Pardubice	4,519	2
Vysočina (Kraj Vysočina)	Jihlava	6,796	8
South Moravian (Jihomoravský kraj)	Brno	7,188	10
Olomouc (Olomoucký kraj)	Olomouc	5,272	4
Zlín (Zlínský kraj)	Zlín	3,963	3
Moravian-Silesian (Moravskoslezský kraj)	Ostrava	5,427	6

Slovakia

The radiation monitoring network is operated by the Slovak Hydrometeorological Institute (Slovenský hydrometeorologický ústav, SHMÚ), state-subsidised organisation operating under the Slovak Ministry of Environment [6].

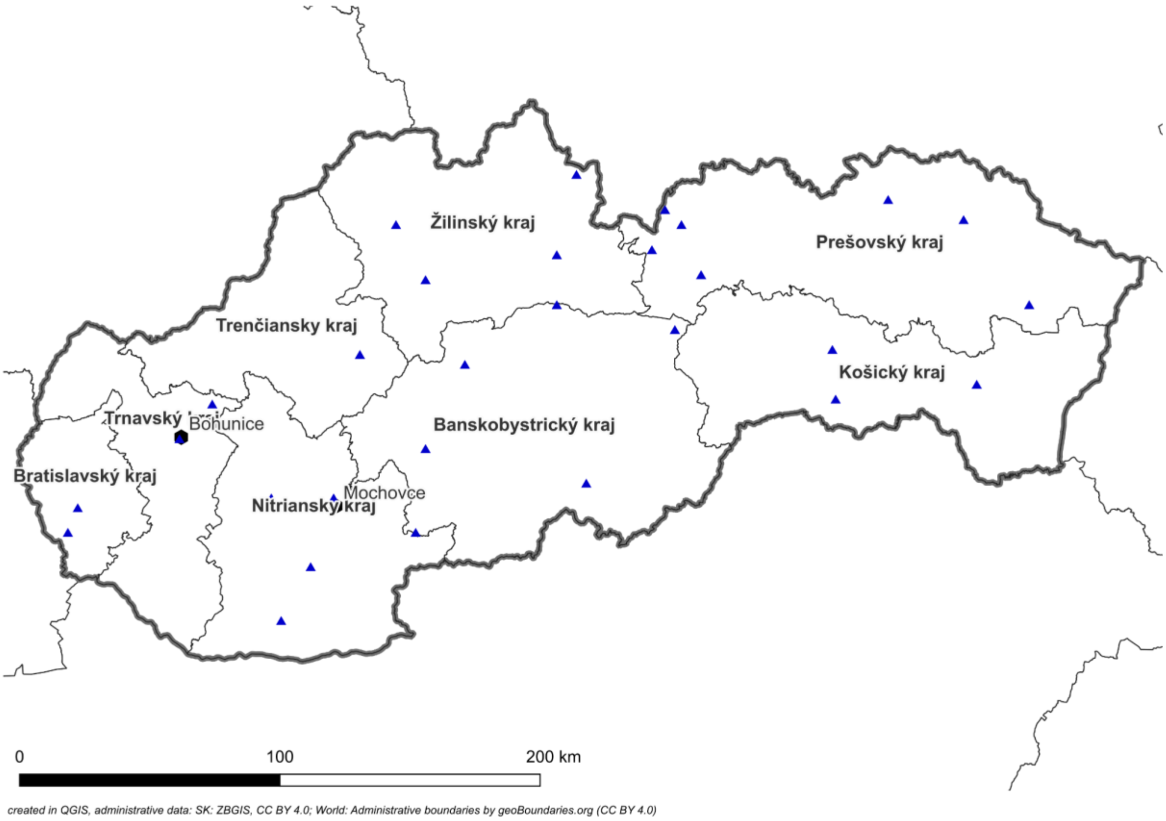

Figure 3. EWN stations (blue triangles) in Slovakia

The network consists of 30 stationary stations with Geiger-Müller type detectors. Automatic real-time measurement of gamma radiation power has been carried out since 1991 and is one of the responses to the experience with the Chornobyl disaster.

Table 4: EWN stations in Slovakia by region

Region (kraj)	Capital	Area (km^2)	EWN stations
Banská Bystrica (Banskobystrický kraj)	Banská Bystrica	9,455	5
Bratislava (Bratislavský kraj)	Bratislava	2,053	2
Košice (Košický kraj)	Košice	6,752	3
Nitra (Nitriansky kraj)	Nitra	6,343	5
Prešov (Prešovský kraj)	Prešov	8,975	7
Trenčín (Trenčiansky kraj)	Trenčín	4,502	2
Trnava (Trnavský kraj)	Trnava	4,172	2
Žilina (Žilinský kraj)	Žilina	6,808	4

Slovak nuclear power plants are located in the Nitra (NPP Mochovce) and Trnava (Jaslovské Bohunice NPP) regions.

The EWN stations are deployed at professional meteorological stations, airports and automatic meteorological stations throughout Slovakia. The probes are placed at a standard height of 1 m above the ground and connected to the SHMÚ data network. The data is provided at an interval of 1 min.

Poland

The system of national monitoring of the radiation situation is operated by the National Atomic Energy Agency of Poland (Państwowa Agencja Atomistyki, PAA). It currently consists of 65 gamma dose rate measuring PMS stations (PMS = Permanent Monitoring Station) for realtime monitoring. Since 2016, the network has been significantly expanded with the installation of many stations mainly on the eastern border of Poland (regions neighbouring Belarus and Ukraine) [7].

Figure 4. EWN stations (blue triangles) in Poland

The network is also supplemented by advanced monitoring sites for spectrometric measurements, monitoring of radionuclides in the air (aerosol samplers), etc. and also includes 9 advanced monitoring stations of the Institute of Meteorology and Water Management (Instytut Meteorologii i Gospodarki Wodnej, IMGW).

Table 5: EWN stations in Poland by region

Voivodeship (województwo)	**Capital city/cities***	**Area (km^2)**	**EWN stations**
Lower Silesian (*dolnośląskie*)	Wrocław	19,947	3
Kuyavian-Pomeranian (*kujawsko-pomorskie*)	Bydgoszcz, Toruń	17,971	1
Lublin (*lubelskie*)	Lublin	25,123	16
Lubusz (*lubuskie*)	Gorzów Wielkopolski, Zielona Góra	13,988	1
Łódź (*łódzkie*)	Łódź	18,219	1
Lesser Poland (*małopolskie*)	Kraków	15,184	3
Masovian (*mazowieckie*)	Warszawa	35,559	3
Opole (*opolskie*)	Opole	9,412	1
Subcarpathian (*podkarpackie*)	Rzeszów	17,845	11
Podlaskie (*podlaskie*)	Białystok	20,187	11
Pomeranian (*pomorskie*)	Gdańsk	19,547	2
Silesian (*śląskie*)	Katowice	12,334	2
Świętokrzyskie/Holy Cross (*świętokrzyskie*)	Kielce	11,709	1
Warmian-Masurian (*warmińsko-mazurskie*)	Olsztyn	24,174	3
Greater Poland (*wielkopolskie*)	Poznań	29,827	1
West Pomeranian (*zachodniopomorskie*)	Szczecin	22,910	3

As part of the development of nuclear energy in Poland (planned construction of NPP and SMR), the number of PMS stations should increase to 150 by 2033.

Network density

The EWN network density comparison included dose rate measurement stations whose data are shared with EURDEP – using data on station positions from EURDEP/Joint Research Centre Data Catalogue, SHMÚ and PAA [6][7][8].

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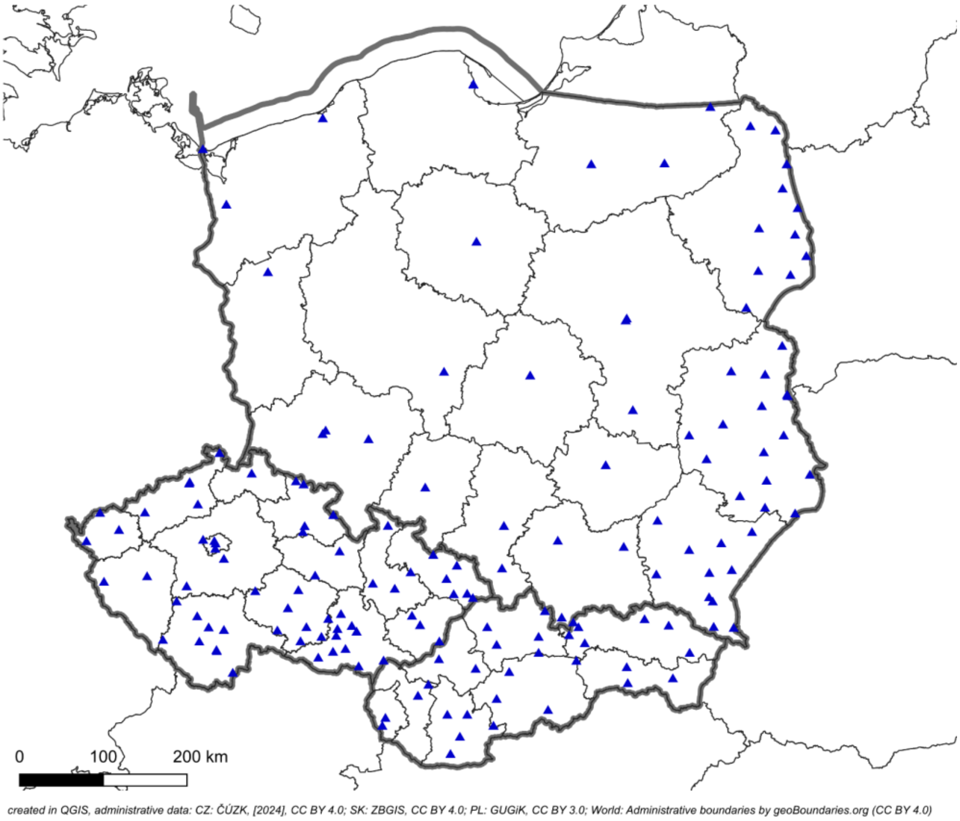

Figure 5. Dose rate monitoring EWN stations in Czechia, Slovakia and Poland

As of November 27, 2025, 64 stations measuring online gamma dose rates were available for Czechia, 30 for Slovakia and 63 for Poland - (PMS stations + IMGW stations).

Table 6: Number of EWN stationary gamma dose rate measurement stations per country

	Area (km^2) [9]	EWN stations
Czechia	78,871	64
Slovakia	49,035	30
Poland	311,928	63

The Czech Republic has the densest network of EWN stations of all countries - approximately one station per each 1,232 km^2. For Slovakia it is one station per 1,635 km^2, and for Poland one per 4,951 km^2 - heterogeneous distribution, with a higher density of stations on the eastern border - however, one should take into account that Poland does not yet have any NPPs.

Of course, the above values do not take into account the spatial distribution of stations across the country. Better information can be provided by tables showing the number of stations in individual regions (CZ/SR - kraj, PL - voivodeship) - see the previous section.

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A useful indicator can be the so-called distance matrix. In this case, it was calculated in a geographic information system QGIS from vector point layers with station positions for individual countries using the QGIS Distance matrix tool [10]. The tool calculates for point features distances to their nearest features in the same layer or in another layer. In this case, the distance from each EWN station to the nearest EWN station was calculated for each country.

Table 7: Distance matrix results per country

distance (km)	Czechia	Slovakia	Poland
minimum	1.23	8.23	0.51
maximum	58.80	67.63	171.90
Average	21.73	24.97	43.91

Czechia and Slovakia have comparable values of the distance to nearest EWN station - average distance about 22-25 kilometers and the maximum about 58-68 kilometers. Poland has significantly higher distances - with average about 44 kilometers and the maximum 172 kilometers.

2 Nuclear accidents – lessons learned

In addition to military nuclear tests, the approach of the public to radioactivity was greatly influenced by two major nuclear power plant accidents - the 1986 Chornobyl accident in the then Soviet Union (now Ukraine) and the 2011 Fukushima nuclear power plant accident in Japan.

While the Chornobyl accident mainly affected the monitoring and countermeasure systems in Czechoslovakia and Poland, the Fukushima accident essentially kicked off the phenomenon of citizen radiation measurements (see chapter 2.2).

2.1 Chornobyl NPP accident - historical experience and consequences

The Chornobyl accident on April 26, 1986 caused 29 immediate human casualties, followed by other deaths and illnesses with permanent consequences. The effects of the accident are visible not only in the former Soviet Union, but also in Europe. In addition to the direct effects (radioactive contamination), it has also caused many people to distrust the use of nuclear energy and anything related to radioactivity.

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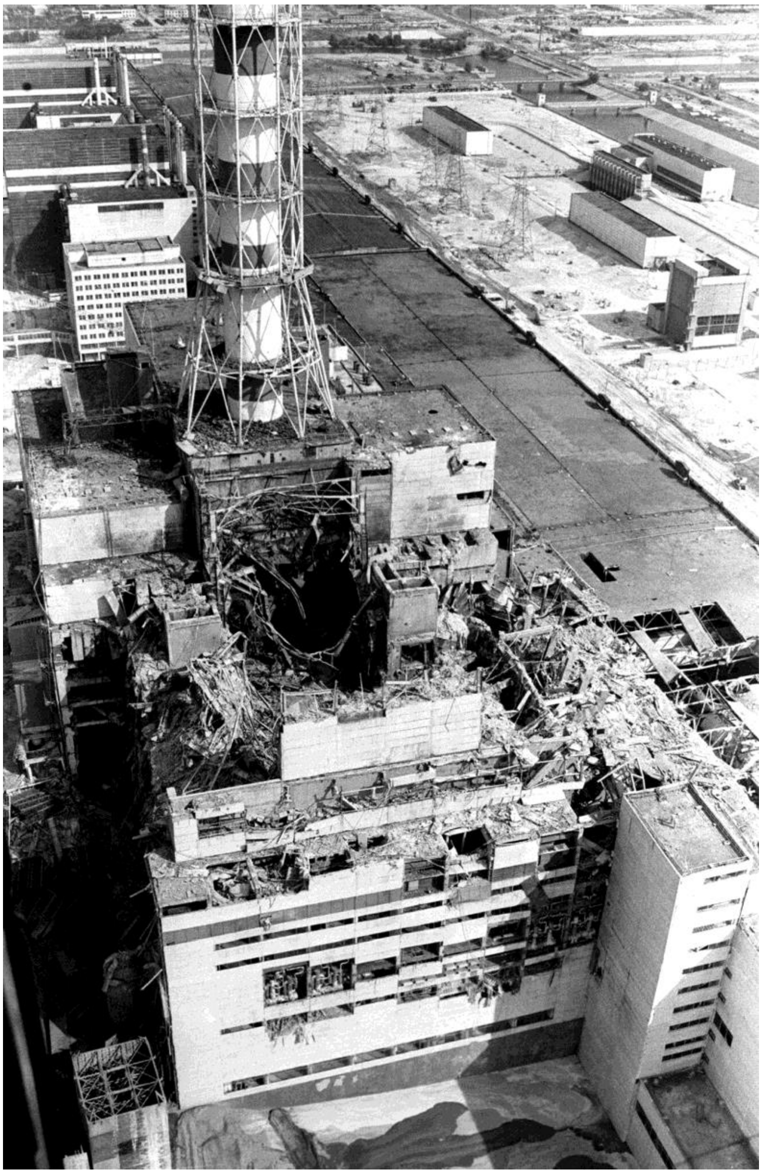

Figure 6. Reactor 4 several months after the disaster.
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As a result of a combination of operator errors during a planned experiment [11, 12], the No. 4 reactor of the Chornobyl Nuclear Power Plant (Ukrainian: Чорнобильська AEC (ЧАЕС)), located near Pripyat, Ukrainian SSR, Soviet Union (now Ukraine) exploded on April 26, 1986. The explosion scattered part of the reactor core into the surrounding area, and a graphite moderator fire occurred.

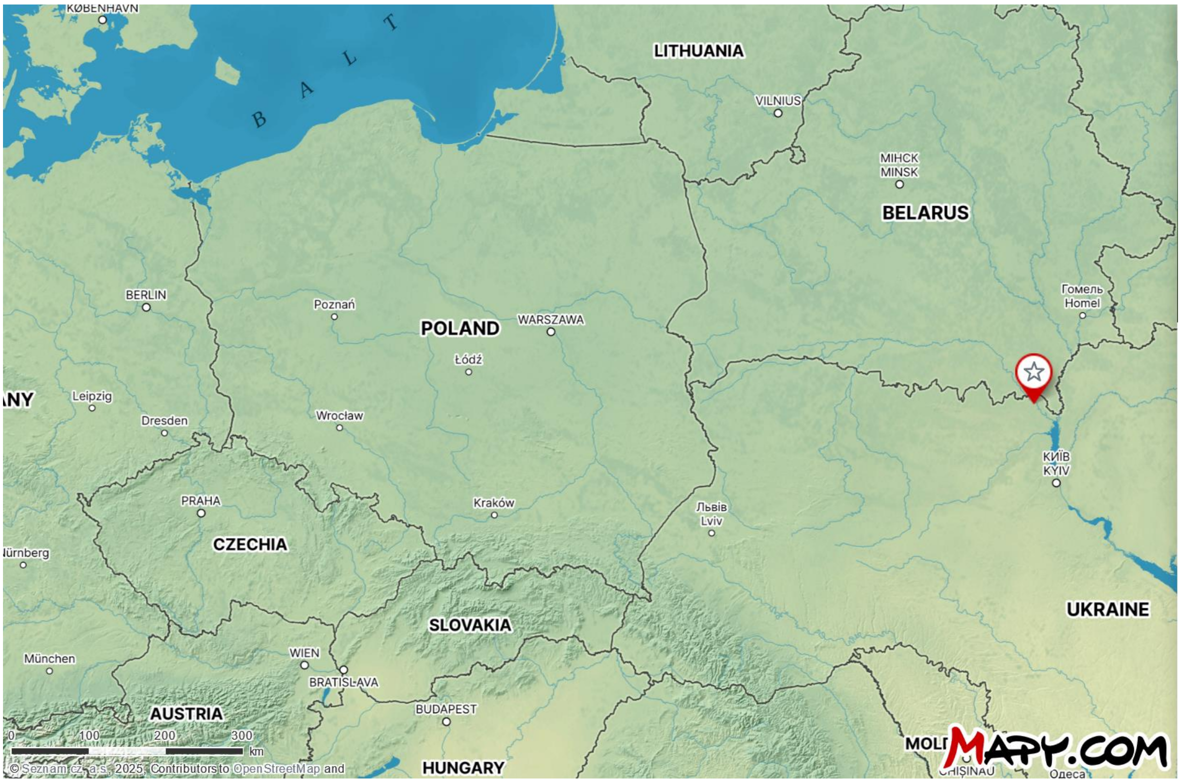

Figure 7. Position of the Chornobyl Nuclear Power Plant (ChNPP)

The fire eventually continued until May 14, and there was a massive release of radioactivity into the air. The cloud from the burning reactor dispersed large amounts of radioactive materials, especially radioactive iodine (characterized by high volatility) and caesium, over much of Europe. Radioactive iodine (I-131) affects the thyroid gland the most, has a short half-life (about 8 days) and has mostly decayed within a few weeks of the accident. Radioactive caesium (Cs-137) has a half-life of about 30 years and is still measurable in selected components of environment like soil and some foods in many parts of Europe. The highest concentrations of contamination occurred in large areas of the Soviet Union around the power plant, which now includes the territories of Belarus, Russia and Ukraine, see Fig. 7. [13]

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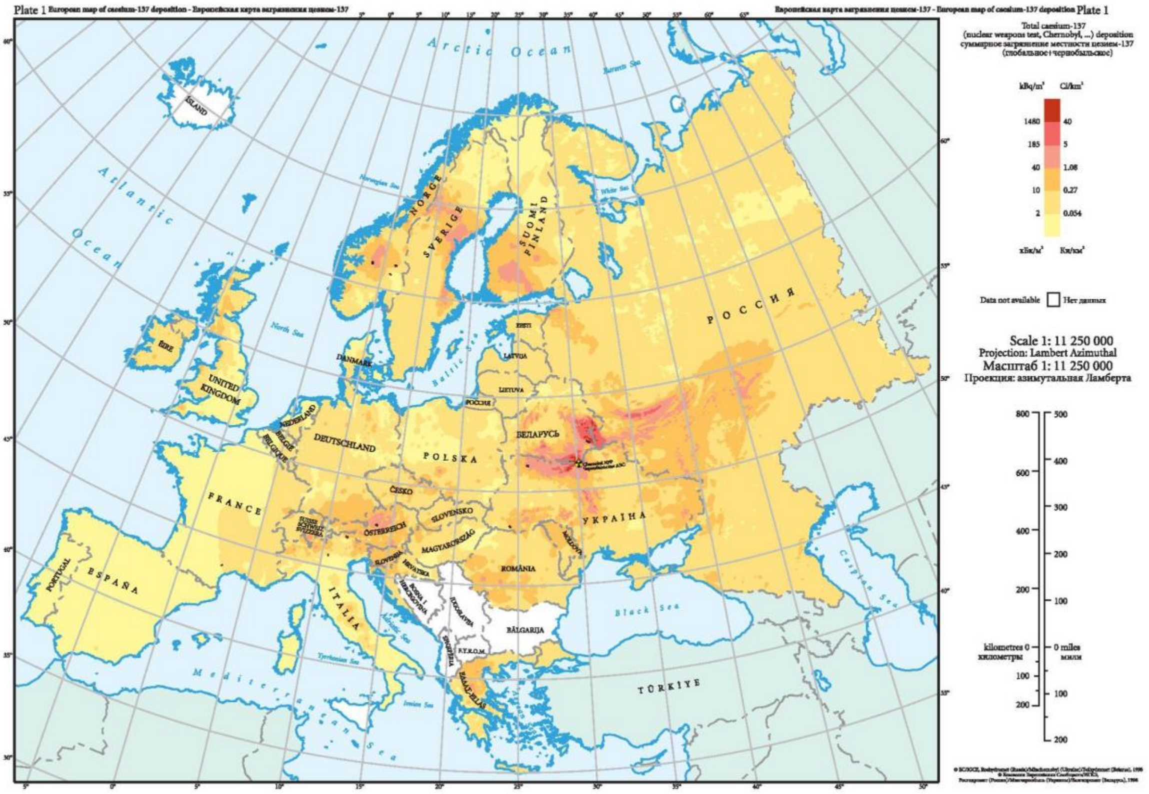

Figure 8. Cs-137 contamination in Europe (1998) [13]

In the immediate aftermath of the 1986 Chornobyl disaster, citizen-led radiation measurements were severely limited due to strict Soviet state secrecy and a lack of available equipment for the public. The Soviet government initially withheld data on the accident's severity. Information was presented as "under control," and official maps of contamination were not released to the public until 1989 (Pravda, March 20, 1989). Public access to active dosimeters was non-existent in the USSR during the first years of the disaster. In the 1990s, as the USSR collapsed, researchers and voluntary movements began providing more independent assessments of health effects and radiation levels. In the early 1990s consumer-grade radiation detectors like the Bella or Anri began to be manufactured for purchase by private individuals.

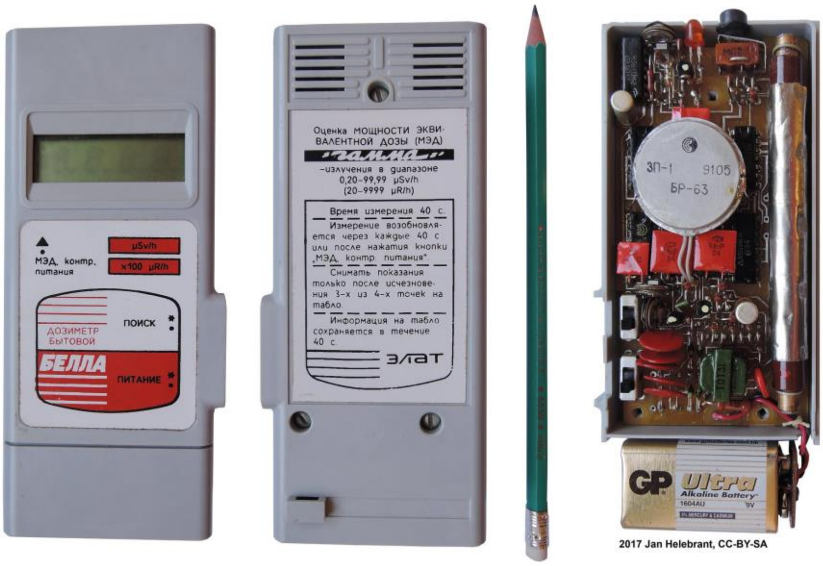

Figure 9. Bella detector (photo by Jan Helebrant, CC BY-SA, Flickr.com)

These devices were among the first "household" radiation detectors mass-produced in the Soviet Union during the late 1980s and early 1990s as a direct response to public demand for transparency after the Chernobyl disaster. Both radiometers were using SBM-20 Geiger Muller tubes, which saturated at high dose-rates.

Figure 10. Anri 01-02 "Sosna" detector (photo by Karel Svoboda, CC BY-SA, Flickr.com)

Anri 01-02 "Sosna" utilized four SBM-20 tubes to increase sensitivity, reduced measurement time and differentiate between gamma-rays and beta-rays, The release of the

Bella and Anri marked a shift toward individual radiation safety and are considered the ancestors of today's "citizen science" equipment.

2.1.1 Czechia and Slovakia

In 1986, the Czech Republic and Slovakia were part of one state - Czechoslovakia (officially Czechoslovak Socialist Republic, Czech and Slovak: Československá socialistická republika, ČSSR, 1960-1990) under communist rule, and regarded as a satellite state in the Soviet sphere of interest.

In Czechoslovakia, at the time of the Chornobyl accident, state supervision over radiation protection was the responsibility of the Ministries of Health of the Czech Republic and the Slovak Republic and was carried out by the activities of both chief hygienists and regional hygienists.

The relevant experts worked at the Radiation Hygiene Centre of the Institute of Hygiene and Epidemiology (in Czech: Centrum hygieny záření, Institut hygieny a epidemiologie, IHE) in Prague, in Slovakia at the Research Institute of Preventive Medicine (in Slovak: Výskumný ústav preventívneho lekárstva) in Bratislava, and then in the radiation hygiene departments of the Regional Hygiene Stations and in the specialized Institute of Occupational Hygiene in the Uranium Industry (in Czech: Ústav hygieny práce v uranovém průmyslu) (since July 1, 1995, the competences of supervision in radiation protection have been transferred to the State Office for Nuclear Safety (in Czech: Státní úřad pro jadernou bezpečnost, SÚJB). Its professional base is now the National Radiation Protection Institute (in Czech: Státní ústav radiační ochrany, SÚRO).

Radiation hygiene experts were knowledgeable about the issue of radiation accidents and related international documents - in particular, publications of the International Atomic Energy Agency (IAEA) from 1981 and 1985, the World Health Organization (WHO) from 1984 and the International Commission on Radiological Protection (ICRP) from 1984.

One of the results of the efforts of radiation protection and nuclear safety experts was the publication of the Civil Protection Manual "Protection of the Population and Measures in the National Economy in the Event of a Radiation Accident at a NPP" (Ochrana obyvatelstva a opatření v národním hospodářství při radiační havárii JEZ), approved in September 1980 and which already covered the issue of severe NPP accidents, on the occasion of the start-up of the V1 NPP in Jaslovské Bohunice in Slovakia.

Soon after, the Commission of the Government of the Czechoslovak Socialist Republic for the Coordination of Measures in the Event of a Radiation Accident at the Nuclear Power Plant was established, the statute of which was approved by the government in 1981.

On 13 February 1986, the Government Emergency Commission approved the Directive on the Principles of Monitoring in the Event of a Radiation Accident at the Nuclear Power Plant. This Directive did not consider the possibility of a major nuclear accident affecting the territory. Therefore, it was not optimal for the situation of the Chernobyl accident, but the prepared system could have been put into operation immediately.

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The arrival of the radioactive cloud in Czechoslovakia was first detected during the night of 29 to 30 April 1986, as in other countries, by nuclear power plants as part of control measurements [11, 12]. In the morning, measurements also began at some radiation hygiene departments of the Regional Hygiene Stations and at the Radiation Hygiene Center (IHE), which was tasked with collecting data on the radiation situation.

The most important contaminants were identified as iodine I-131, caesium Cs-137 and Cs-134. Iodine 131 contributed significantly to the doses in the first period, but its importance later decreased due to its short half-life (8 days). Since July 1986, more than 90% of the doses were made up of caesium 134 and 137 [11, 12]. Based on measurements of the activity of radionuclides in the air and in fallout and dose rate measurements, very conservative estimates of doses to the population and predictions of their time evolution were first made. The estimated doses were well below the values for which countermeasures were recommended (ICRP Recommendation No. 40 etc.).

In addition to regular monitoring of the radionuclides in the air and dose rate measurements, measurements of the content of radionuclides in milk was introduced on May 1st, and later also in drinking water and other foods. In order to predict the time course of contamination of milk and meat, measurements of the content of radionuclides in feed were started.

Communication with the public

The extent and transparency of information regarding the accident at the time reflected the prevailing political and social context. Initially, authorities withheld details about the incident, but a significant part of Czechoslovakia was covered by radio broadcasts from Voice of America and Radio Free Europe, so many people knew about the accident a few days later. On April 29, the official newspaper “Rudé právo” (Czech: “Red Justice” or “The Red Right”)[15] published a brief mention of the accident and "damaged reactor", stating that the consequences were being eliminated and that "similar accidents have already occurred many times in the world". A day later, the same newspaper again reported very briefly that “no increase in radioactivity” had been detected in Czechoslovakia and that continuous measurements were being carried out.

Czechoslovakia responded to the situation by establishing a government emergency commission, which met for the first time on May 1, e.g. 5 days after the accident. After assessing the situation, the Commission adopted measures in the areas of agriculture and nutrition, foreign trade, the Ministry of the Interior, transport, health and finally in the information sector, where the main task was to "prevent hysteria". Paradoxically, the news media later had to be regulated because the excess of information that the media began to bring about nuclear power plant accidents around the world could have worked against their construction in Czechoslovakia. [16]

Only on May 1st did the government issue a statement that radioactivity measurements in individual regions show that "the health of the population is not at risk and therefore no special measures need to be taken." In a further statement on May 5, the authorities admitted a slight increase in radioactivity. [15, 16] Contrary to an earlier report

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denying increased radioactivity, the media reported that radioactivity levels were already decreasing.

The chief hygienist appeared on the radio 10 days after the accident. She admitted that "the measured values are higher than usual" and also that "in the first days an increase in radioactive substances was detected." She did not list any countermeasures but said that "it is of course assumed that people will observe all principles of personal hygiene, including washing fruits and vegetables before eating." [16]

However, citizens did not trust the government very much and sought information wherever possible, primarily in foreign, mainly Western, but also Polish and Hungarian media. The orientation towards "foreign" media is also evidenced by a public opinion poll conducted in 1986. According to the report, most citizens were worried about the possible consequences of the accident. 18% of those surveyed had great concerns about their own health or the health of their family/relatives, 55% of citizens were somewhat concerned, and 27% of respondents had no concerns. [16]

The research also states that 44% of the population, according to their own statements, changed their habits and took some steps to protect themselves from radioactive fallout (most often limiting the consumption of certain types of food, increasing personal hygiene and limiting outdoor activities / children's walks). Almost half of the population followed the recommendations in Western media to some extent. [16]

Resulting countermeasures

The contamination in Czechoslovakia occurred at the beginning of the growing season, when only grass and some leafy vegetables (lettuce, spinach, etc.) were grown (and only partially). In the period at the turn of April and May, the livestock were only switching to green feed.

The most significant contaminants were I-131, Cs-137, and Cs-134. I-131 was the main contributor to the doses at the beginning of the period, but its importance decreased due to its short half-life (8 days). The mass activities of significant radionuclides in grass ranged from hundreds to thousands of Bq/kg, but decreased relatively quickly due the decay of short lived radionuclides. [12]

The main attention was on monitoring the content of radionuclides in milk and dairy products (from May 1st), because these products were the most significant source of intake of I-131, Cs-137 and Cs-134. Later, drinking water and feed also began to be monitored.

The monitoring was focused on 25 selected dairies geographically evenly distributed across the territory of Czechoslovakia. Production of these diaries covered 30% of all direct milk consumption. In addition, several nationwide surveys were carried out in May, June and December 1986, covering all dairies in the state.

The activity of I-131 in milk from dairies after May 15, 1986 did not exceed the intervention level of 1000 Bq/l at any location and the milk from the selected dairies was sufficiently representative for the entire state. The content of Cs-137 in milk samples from the selected 25 dairies is being monitored up to the present time [12].

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Milk with I-131 activity higher than 1,000 Bq/l was excluded from consumption (WHO recommendation – exclude milk with activity higher than 2,000 Bq/l). Stocks of dried and condensed milk were released for consumption.

Special attention was paid to the production of infant formula. Several countermeasures were implemented, which practically eliminated the presence of radioactive iodine from infant formula. The measures included, for example, moving the production of baby milk formula to other dairies or changing the milk supplier to less affected regions.

Of the other foods, those that are most important in terms of consumption by the population were monitored, i.e. in addition to milk, mainly meat, then cereals, vegetables and fruits.

Increased sprinkling of roads in cities was also recommended. A specific measure for Slovakia was iodine prophylaxis for sheep herders due to high levels of radioactive iodine in sheep's milk (150 - 75,000 Bq/l).

Considering that the measured activities and doses did not require the introduction of protective measures according to the then Czechoslovak and international regulations, only such measures were introduced that did not interfere with people's lives and required minimal financial costs.

Environmental impacts

The only remaining impact of the Chornobyl fallout to this day is the still detectable levels of Cs-137 (using sensitive airborne gamma spectrometry with high-volume NaI(Tl) detectors or in-situ HPGe spectrometry) in some regions of Czechia - for example Bohemian Forest (Czech: Šumava) and on the German side the Bavarian Forest (German: Bayerischer Wald). Higher values of Cs-137 in the soil cause the occurrence of so-called "radioactive boars" - due to the way of feeding and composition of their diet, caesium is concentrated in the boar's tissues. This problem is well known and in both countries, caesium levels in boar meat have been monitored since 1986 and if the limit value (600 Bq/kg) is exceeded, the meat is not allowed to be consumed. In some regions, more than half of the samples exceeded the limit value, with the highest measured value being more than 22,000 Bq/kg. [17]

Impacts on the support of nuclear energy in the future

Unlike some European countries, in the case of Czechoslovakia, the impact of the Chornobyl accident was not such that it led, for example, to the termination of the construction of nuclear power plants in the country.

In fact, the only two power plants in the Eastern bloc that began construction after the Chornobyl accident are Temelín in the Czech Republic and Mochovce in Slovakia. Construction of Temelín began in 1987; the first unit began supplying electricity in 2000, the second two years later. Construction of the first and second units of the Slovak Mochovce nuclear power plant began in 1983. The first unit was put into operation in 1998, the second in 2000. The construction of two more units began in 1987, one unit was connected to the grid in 2023, and the last - the fourth - is planned to be completed in 2026.

Czechia has long had the highest support for nuclear energy in the EU [18][19]. In Slovakia and Poland, almost 70% of the population evaluates nuclear energy positively, and all three countries have a higher proportion of residents with a positive attitude compared to the EU. For comparison, we also mention Austria, where the majority of residents have a negative attitude towards nuclear energy.

Table 8. Respondents' attitude towards nuclear energy according to Special Eurobarometer SP557: European citizens' knowledge and attitudes towards science and technology 2024 and 2021 surveys.

*QA6a.8. The following is a list of areas where new technologies are currently being developed. For each of these, do you think it will have a positive, a negative or no effect on our way of life in the next 20 years? - **Nuclear energy for energy production***										
	EU		Czechia		Slovakia		Poland		Austria	
	2021	2024	2021	2024	2021	2024	2021	2024	2021	2024
Total 'Positive'	46 %	56 %	79 %	77 %	67 %	64 %	60 %	69 %	30 %	25 %
Total 'Negative'	46 %	35 %	19 %	17 %	24 %	26 %	31 %	23 %	66 %	67 %

Annual public opinion polls (STEM and IBRS agencies) show high support for nuclear power in the Czech Republic. A significant drop in support occurred only in 2011 in connection with the Fukushima nuclear power plant accident in Japan - to 54%. Since then, support has grown again - IBRS data for 2024 shows that 66% of the population is in favor of the development of nuclear energy in the Czech Republic [21].

2.1.2 Poland

Environmental and Health Impacts

The Chornobyl accident released a plume of radioactive isotopes, including I-131, Cs-137, and Sr-90, which were carried by wind currents across Europe. In Poland, radioactive contamination initially affected mainly the northeastern part of the country. An increase in air radioactivity was detected by the monitoring station in Mikołajki on April 27, 1986, at 8:00 p.m. For the next 3 days, the I-131 concentration in the air ranged from 0.1 to 200 Bq/m^3. Between May 1 and 3, it ranged from 2–10 Bq/m^3, and for the next 7 days (until May 10) - from 0.2 to 2.8 Bq/m^3. In the most contaminated northeastern region the measured concentration of I-131 in milk reached 3 kBq/kg. Local rains and storms caused heterogeneous deposition of contamination, particularly in southern Poland (Kraków and Opole regions). The calculated thyroid doses in Poland, depending on the use of iodine prophylaxis and the consumption of fresh milk and vegetables, were in the range of 2–87.5 mSv for children up to 1 year of age, 2.5–52 mSv for children up to 5 years of age, 2.4–41.5 mSv for children up to 10 years of age, and 1.6–23 mSv for adults. [23]

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The primary health concern was the increased risk of thyroid cancer due to exposure to radioactive I-131, particularly in children and adolescents. This risk was highly reduced by the administration of stable iodine to children and young adults. As a result, the contamination resulting from the Chornobyl disaster did not cause an increase in the incidence of thyroid cancer during the first 4 years after the accident. In the years 1992–1993, a statistically significant increase in the incidence of thyroid cancer among hospitalized patients was observed in northeastern Poland compared to 1988–1989 but that was mostly attributed to the improved diagnostic methods. The increase in the incidence of thyroid adenomas and cancers observed by a few authors may be also the result of iodine deficiency in south and central Poland. However, the long-term health impacts remain under study, with some evidence suggesting possible non-thyroid effects, such as mini-satellite instability, though these are less definitive. [24]

Environmental contamination led to restrictions on agricultural products, particularly milk and vegetables, as those that could potentially contain higher concentrations of radioactive isotopes. The fallout also affected Poland’s agricultural sector, with losses in output and restrictions on harvesting certain crops, contributing to economic and social disruption. The psychological impact was significant, with public anxiety and fear of radiation leading to widespread concern, exacerbated by initial delays in official information. [24]

Public information

The dissemination of information in Poland following the Chornobyl accident was heavily influenced by the country’s status as a satellite state of the Soviet Union. The Soviet government delayed public acknowledgment of the disaster, with no official reports released until April 28, 1986, when Swedish authorities, detecting elevated radiation levels, prompted the Soviet Union to admit the accident. In Poland, the government did not immediately issue an official statement, and the media remained silent on April 26 and 27. The lack of timely official communication led to public confusion. For example, no restrictions were imposed on outdoor activities, and the national May Day march on May 1, 1986, proceeded as planned, potentially exposing participants to radioactive fallout. The absence of clear guidance on safety measures, such as avoiding contaminated food or staying indoors, heightened public anxiety. Personal accounts from the time indicate that informal warnings circulated, advising against consuming salad, mushrooms, or milk, but these were not officially sanctioned. The delayed and limited communication reflected the Soviet-influenced political priorities, which placed secrecy over public health. [25]

Measurements taken

Poland’s response to the Chornobyl fallout included extensive radiation monitoring, coordinated by the Central Laboratory for Radiological Protection (CLOR) and the Polish National Atomic Agency. Following the detection of elevated radiation levels on April 28, 1986, additional measurements were conducted to assess the extent of contamination. Monitoring stations across the country tracked air radioactivity, while environmental samples, including soil, water, and foodstuffs, were analyzed to determine radionuclide concentrations. In 1986, the system was based mainly on manual sampling and subsequent laboratory analysis, which differs from today's network of automatic early detection stations that transmit data in real

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time. The measurements were coordinated by the Central Laboratory for Radiological Protection in Warsaw, which collected data from regular and ad-hoc organized measurement laboratories, in particular National Institute of Public Health (NIZP-PZH) in Warsaw, which performed radiological analyses of foodstuffs, milk, and human exposure indicators, Institute of Nuclear Research – Otwock/Świerk, which provided spectrometric analyses and research support in radiological measurements, Institute of Nuclear Physics – Kraków, with spectrometry, food analysis and dosimetry, Main Institute of Mining, Institute of Meteorology (IMGW), Military Institute of Hygiene and Epidemiology and the Military Institute of Chemistry and Radiometry. They were supported by regional sanitary–epidemiological laboratories (part of the health services) conducted routine analysis of environmental and food samples for radioactivity.

The Polish authorities, in collaboration with the USSR Ministry of Health and other agencies, assessed the pathways of radioactive contamination through the food chain. Time-limited radiation dose standards were established: 100 mSv for the first year, 30 mSv for the second, 25 mSv for the third, and 25 mSv for the fourth year. These standards guided the monitoring of internal and external radiation exposure.

Countermeasures Implemented

Poland implemented one of the most significant countermeasures in response to the Chornobyl fallout: the rapid distribution of stable iodine to protect against thyroid cancer caused by I-131. Between April 29 and May 1, 1986, approximately 18.5 million people, primarily children, received a single dose of stable iodine to block the uptake of radioactive iodine by the thyroid gland. This prophylactic action, initiated by Professor Jaworowski and executed by the Ministry of Health, was described as the largest of its kind in medical history. The stable iodine distribution was performed just in three days using the system originally prepared in case of nuclear war. [26]

The decision to administer stable iodine was based on the International Commission on Radiological Protection (ICRP) recommendation to implement prophylaxis at a thyroid dose of 50 mSv. Despite some retrospective critique, the iodine distribution likely reduced the incidence of thyroid cancer in Poland compared to regions with less proactive measures. The country's rapid iodine distribution is cited as a model for radiological emergency response [27].

Additional countermeasures included restrictions on consuming contaminated foodstuffs, such as milk, leafy vegetables, and mushrooms, which were major sources of I-131 and Cs-137. Agricultural authorities issued guidelines to limit the use of contaminated produce, and some areas faced restrictions on harvesting wild food products. These measures aimed to reduce internal radiation exposure but disrupted local economies and food supply chains.

Impacts on the support of nuclear energy in the future

The Chornobyl disaster had a decisive impact on the interruption of the advanced construction of the Żarnowiec nuclear power plant. The Żarnowiec nuclear power plant was to consist of four nuclear units equipped with VVER-440 pressurized water reactors, each with

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an electrical output of approximately 440 MW. The reactors were designed in the USSR and manufactured at the Skoda plant in former Czechoslovakia. Commissioning of the first unit, with an installed capacity of 465 MWe, was originally planned for 1989, and the second for 1990. On May 27, 1990, a local referendum was held in the Gdańsk Voivodeship regarding the further construction of the plant. With a turnout of 44.3% of eligible voters, 86.1% voted against the construction, and 13.9% supported it. On December 17, 1990, the Polish government adopted a resolution to stop the construction of this first nuclear power plant in Poland. It took another 20 years before the decision was made in Poland to start construction of the new nuclear power plant.

2.2 Fukushima nuclear accident and related citizen radiation measurements

The Fukushima Daiichi Nuclear Power Plant accident on March 11, 2011 in Fukushima, Japan is regarded as the worst nuclear incident since the Chornobyl disaster in 1986 and the only other which is the only other nuclear accident with the highest - 7 - rating on the international nuclear and radiological event scale (INES).

Unlike the Chornobyl accident, the cause was not the human factor (in Chornobyl it was a combination of the experiment being conducted and several violations of safety measures) but a natural disaster. The direct cause was the Tōhoku earthquake and resulting tsunami wave.

It was the most powerful earthquake ever recorded in Japan, and the fourth most powerful earthquake recorded in the world since modern seismography began in 1900. The earthquake triggered powerful tsunami waves that may have reached heights of up to 40.5 m in Miyako in Tōhoku's Iwate Prefecture, and which, in the Sendai area, traveled at 700 km/h and up to 10 km inland [30].

The tsunami (13-14 m high) resulted in electrical grid failure and damaged nearly all of the power plant's backup energy sources. The subsequent inability to sufficiently cool reactors after shutdown compromised containment and resulted in the release of radioactive contaminants into the surrounding environment [31][32].

Japan has a radiation monitoring network - similar to the Czech Republic's early warning network in the event of a nuclear emergency, and in addition, a network of other measuring stations at nuclear power plants in accordance with Japanese nuclear safety laws and other regulations. The national network of detectors, called the System for Prediction of Environment Emergency Dose Information (SPEEDI) and the data are published by the Nuclear Safety Division of the Ministry of Education, Culture, Sports, Science and Technology (MEXT)[33].

Immediately after the accident, all institutions around the world involved in radiation monitoring began to closely follow the situation in Japan. Therefore, shortcomings in the published data, which subsequently triggered various citizen activities, were noticed.

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2.2.1 Aggregation, sharing and conversion of radiation monitoring data

MEXT published the values of 10-minute dose rate measurements from the SPEEDI network on its website http://www.bousai.ne.jp/eng/ (no longer available), but not in machine-readable form - in many tables and partially in PDFs.

Marian Steinbach, a user-interface designer based in Cologne, Germany soon began scraping data from SPEEDI website and converting it into a machine-readable CSV format - he published the data on his website (http://www.sendung.de/japan-radiation-open-data/, no longer accessible).

Steinbach's dataset from SPEEDI was followed up by an interactive map of a Norwegian software engineer Geir Engdahl - Japan Radiation Map, still available at http://gebweb.net/japan-radiation-map/ (now redirecting to http://jciv.iidj.net/) [34].

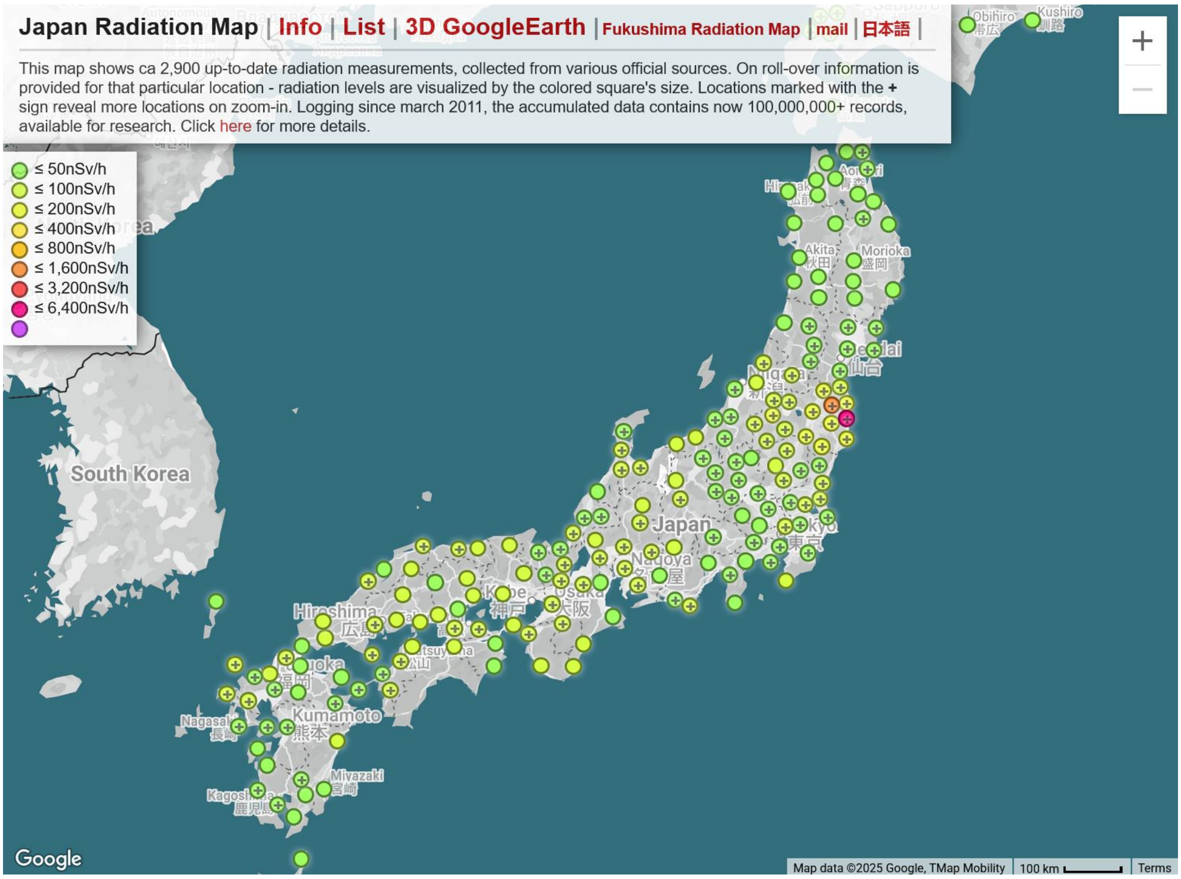

Figure 11. Japan Radiation Map showing dose rate levels from SPEEDI stations.

The dataset provided by Marian Steinbach was also used at SÚRO for the creation of regular dose rate maps of Japan in QGIS.

Some projects, such as Radiocial.org (no longer accessible), have attempted to combine data from different measurement networks into a single interactive map. This

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included unofficial data collection - so-called webscraping - from official websites of various institutions - including SÚRO. The map also included data from various private detectors.

Figure 12. Radiological map showing stations in Germany and Czechia

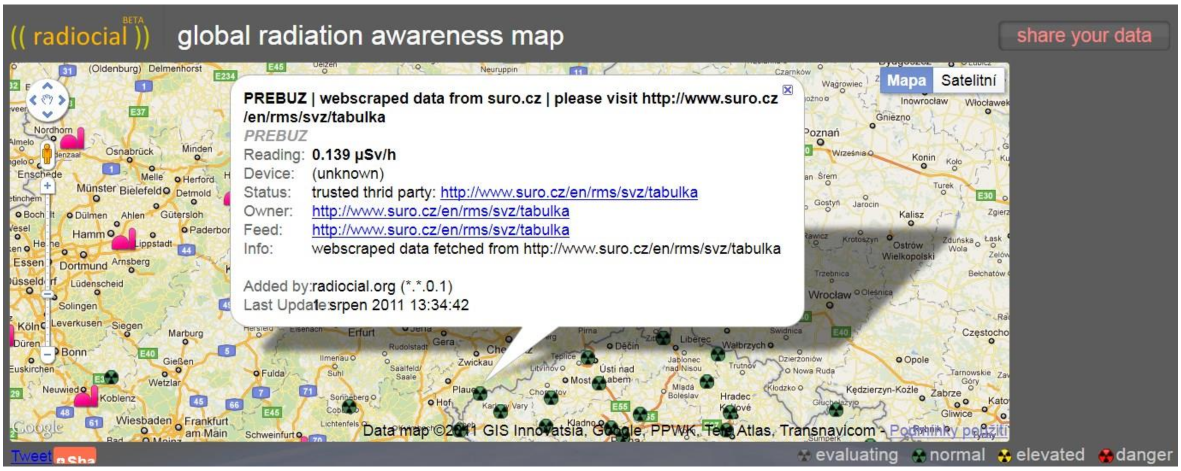

Figure 13. Radiocial map - detail of official Czech EWN station values

2.2.2 Homemade online radiation detectors

At least initially, SPEEDI data was not available for all regions (prefectures) of Japan. The earthquake and subsequent tsunami caused extensive damage to infrastructure, power outages, etc. Even coverage of measurements conducted by professional staff and published on the MEXT website was limited.

Some people were not satisfied with the information provided by official institutions, or considered the method of communication with the public to be insufficient. All affordable dosimeters on the market were sold out very quickly. [36]

A large number of DIY projects emerged - often based on old dosimeters, or old GM tubes. For example, Soviet GM tubes SBM-20 were available on the market relatively cheaply and in large quantities from old stocks. The electronics of the GM counter are not complicated for an electrical engineer, and after connecting to a cheap microcomputer - e.g. an Arduino-type MCU - it makes it possible to build a detector capable of sending measured data to an online service.

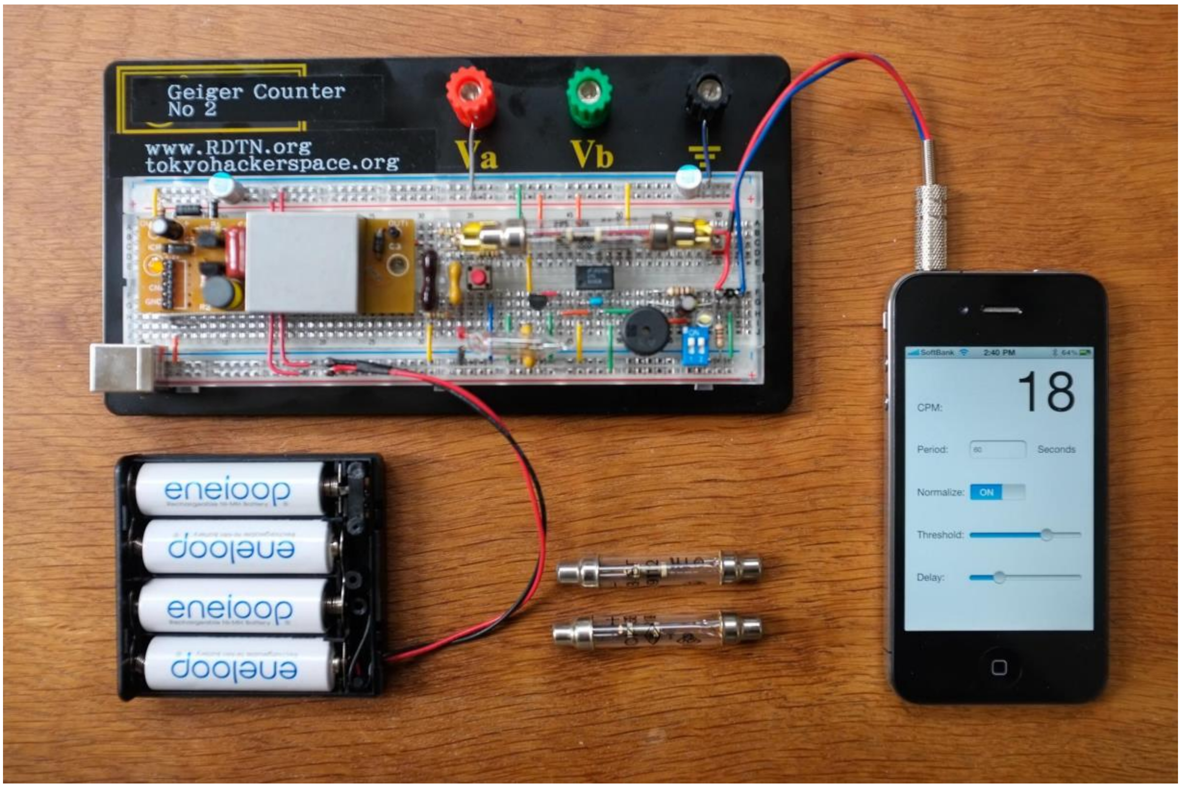

Figure 14. DIY Geiger counter example - the phone is only used here to detect clicks from microphone audio input and calculate the CPM. (photo by Nokton, CC BY-NC, Flickr.com)

This is exactly how so-called IoT (Internet of Things) devices work - for example, a person can remotely monitor data from a smart thermometer at home, soil moisture from another smart sensor in a greenhouse in the garden, etc. These IoT devices only have to comply with a certain format (protocol) for communication or sending data to a particular service provider.

One such service widely used for amateur online sensors at the time of the Fukushima accident was Pachube [35]. Pachube (later Cosm, then Xively, now retired) was founded by Usman Haque in a need to handle real-time data from sensors in interactive environments for his design practice. In 2010, the platform was made available to the public. The following images show screenshots of a web application taken in 2011 with an example of an amateur radiation sensor connected.

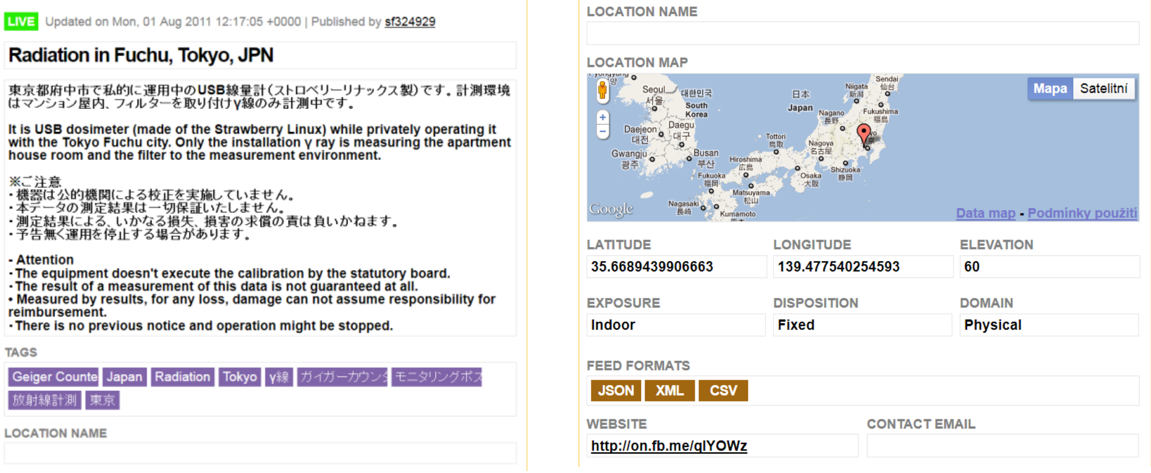

Figure 15. Pachube - description of the connected amateur radiation sensor in Japan

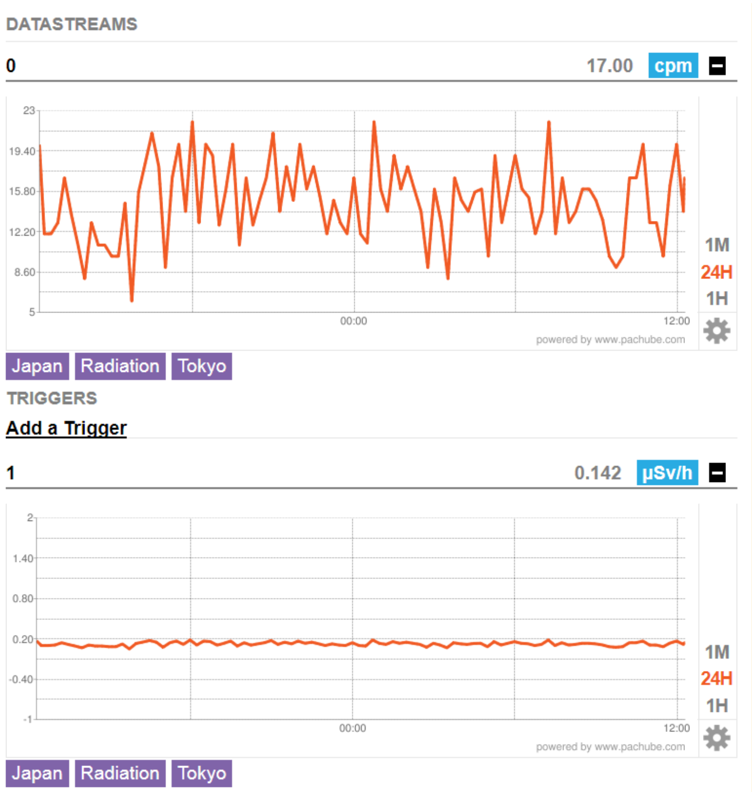

Figure 16. Pachube - data feed from the connected amateur radiation sensor in Japan

2.2.3 SAFECAST, Radioactive@Home, standardization of measurements and instruments

One of the problems of the aforementioned DIY projects was fragmentation - different, often improvised connections of electronics, different types of detectors with different properties, different output data formats.

The following two projects are characterized by the introduction of unified detector hardware and thus increased transparency and reliability of the presented data.

SAFECAST (Japan/USA)

Safecast is one of the most important representatives in the field of citizen radiation monitoring. Its origins date back to the early days after the Fukushima disaster, when Sean Bonner (Los Angeles), Joi Ito (Boston/Dubai/Tokyo) and Pieter Franken (Tokyo), in addition to ensuring that their family and friends were safe, became interested in the possibility of providing them with a radiation detector [36].

Because commercially available devices were sold out almost immediately, the plan changed from purchasing to building their own device. Collaboration was established with International Medcom, a company that manufactures commercial radiation detectors, and with people from Tokyo Hackerspace and others who had experience with electrical engineering.

Subsequently, cooperation was established with the US company Uncorked Studios, which in the meantime was working on the website RDTN.org, primarily intended to aggregate already published radiation data [37].

Initially, commercial devices were used - e.g. Medcom RadAlert100 and Inspector Alert, later used together with Arduino-based additional electronics developed by Tokyo Hackerspace. On May 8, the RDTN project received $36,900 in funding on the Kickstarter platform. On April 24, it was announced that the project name would be changed from RDTN to Safecast.

The first "bGeigie" detectors required a laptop connection to collect geotagged measurements, the newer version of the bGeigie Ninja already had built-in GPS and stored data on an SD card.

Figure 17. Safecast bGeigie detector unit (left) and the bGeigie Ninja console (right).
(photo by Nokton, CC BY-NC, Flickr.com)

The detection unit - a commercial Inspector Alert device - connected to additional electronics, was placed in a durable polycarbonate box attached to the outside of the car window. The measured data was presented in the form of an interactive map and also available for download under CC0 Public Domain license, so without any restrictions for further use.

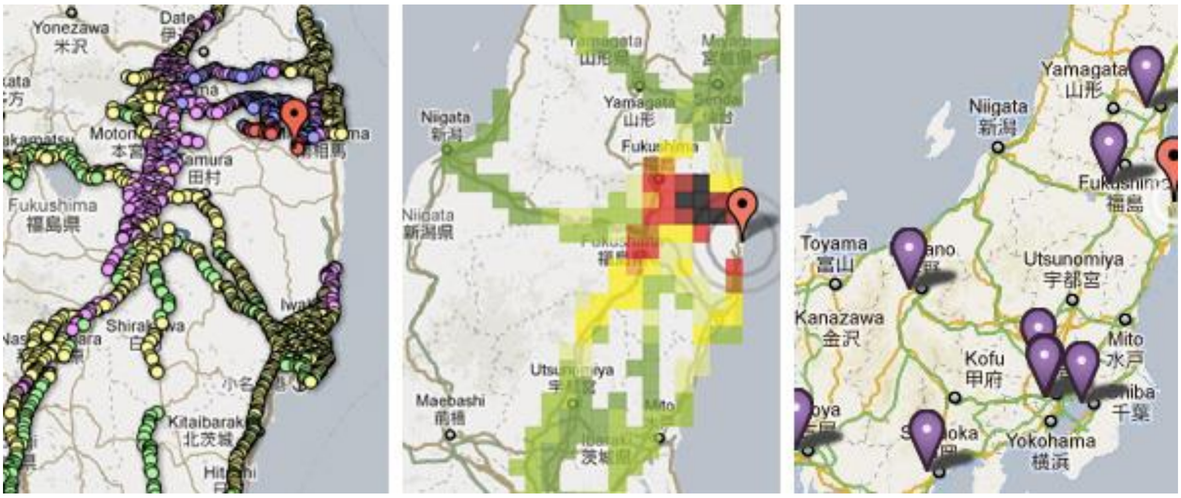

Figure 18. Safecast map - visualisation used in 2011 (Source: Safecast.org)

In October 2011, Safecast announced that the number of data points measured by the bGeigie system exceeded one million. The data also included measurements in the exclusion zone near the Fukushima nuclear power plant - the highest values measured by Safecast to date.

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Figure 19. Safecast bGeigie Nano detector (photo by Jan Helebrant, CC BY-SA, Flickr.com)

A significant milestone in the history of Safecast was the introduction of a compact and lighter version of the bGeigie - the bGeigie Nano. The device could be purchased as a kit or as a complete unit until November 2020. The price of the kit in 2015 was 550 USD, the fully assembled device 1500 USD.

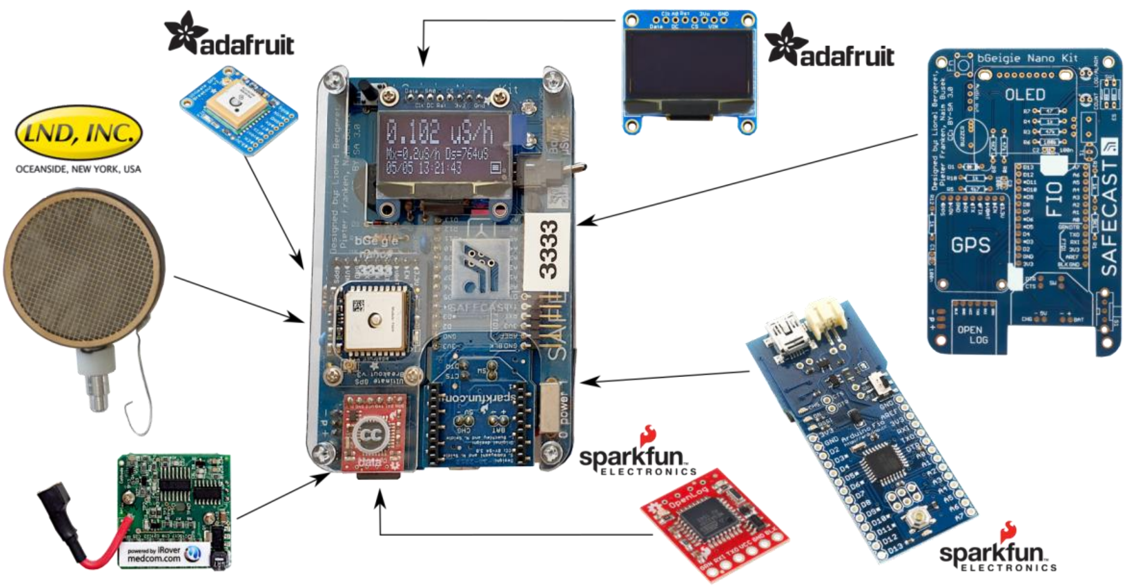

Figure 20. Safecast bGeigie Nano component wiring diagram

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The device was developed in collaboration with International Medcom Inc. and shares some parts with their Inspector Alert detector - the iRover high voltage power supply and the LND 7317 pancake GM tube. According to the Safecast "*bGeigie Nano is a lighter version of the bGeigie Mini using an Arduino Fio, a GpsBee, an OpenLog and an Inspector Alert geiger counter. The aim is to make everything fit in a Pelican Micro Case 1040*".

Several thousand bGeigie Nano devices were produced and contributed greatly to the expansion of the Safecast dataset which reached 200 million data points in February 2023. Production of bGeigie Nano was discontinued by KitHub in 2020, and the development of its successor, called bGeigie Zen, was announced by Safecast in April 2021. bGeigieZen is based on the original bGeigie but uses a new sensor board (but same GM tube by LND, Inc., USA), the SafePulse and M5Stack modular IoT platform. It is bigger than Nano - uses Pelican 1015 case. The device is easier to assemble, as the Zen uses fewer components compared to the bGeigie Nano. The Zen is currently available from the Safecast store (https://bgeigiezen.safecast.jp/store-2/) - a kit to build for 475 USD and a fully assembled device for 750 USD.

Other devices operated by Safecast include various stationary dose rate measurement stations (Solarcast, Pointcast, RadNote) or air quality monitoring (Airnote).

Safecast devices are also involved in monitoring the radiation situation in Ukraine - 10 bGeigie Nanos were loaned by SÚRO as part of the #bgeigies4ukraine initiative in 2022 [38]. Thanks to cooperation with the organizations SaveDnipro and Chornobyl Radiation Ecological Biosphere Reserve, radiation monitoring was carried out in the Chornobyl region using bGeigie Nano devices.

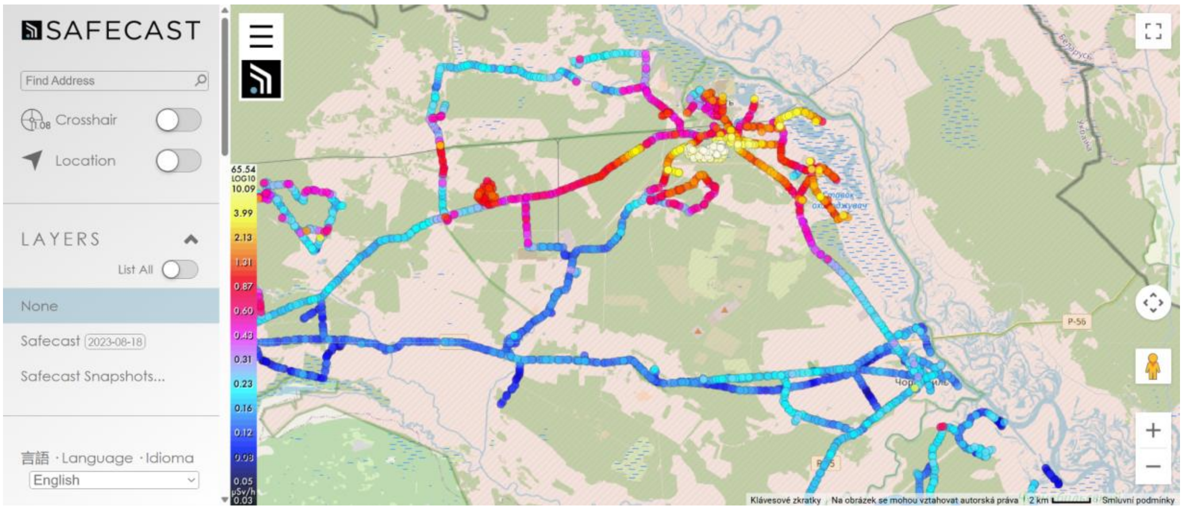

Figure 21. Chornobyl region with #bgeigies4ukraine initiative data (source: Safecast.org)

In this way, over 300 thousand data points were obtained by September 2022 [39], which represented a significant source of information on radiation values. And more or less the only independent and publicly available source of information in Ukraine.

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In August 2024, Safecast and SaveDnipro announced [40] the completion of the first phase of an independent radiation monitoring network in Ukraine. At this stage, 25 RadNote solar-powered stations for realtime radiation monitoring stations were installed. In total, over 100 stations are planned in the network.

Radioactive@Home (Poland)

The Polish Radioactive@Home (http://radioactiveathome.org/en/) project used detectors of its own design, equipped with a GM tube and connected to a computer via USB. Thanks to the built-in LCD display, the detectors can also be used separately when connected to a USB charger / power bank.

The project was launched in April 2011 - on June 2, the establishment of the "BOINC Polska" (BOINC Poland) foundation was announced [41][42][43]. In the alpha phase, testing of detector prototypes was underway. Pre-ordering for the detectors began at the end of July 2011, the first batch of 53 units was sold out by the beginning of August.

Figure 22. Radioactive@Home detector (photo by Jan Helebrant, CC BY-SA, Flickr.com)

The detector had a simple design - a cylindrical plastic case (not suitable for outdoor use), the display was a monochrome LCD. The detection unit was a reliable Soviet-made GM tube - SBM-20, or STS-5 (values of about 30 CPM for natural background).

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Figure 23. Inner part of the detector (photo by Jan Helebrant, CC BY-SA, Flickr.com)

Electronics are very simple, based on a PIC microcontroller. The detectors were offered at a price of 27 EUR, and SÚRO had the opportunity to test them. The detector itself could not send data to the Internet; it required a computer and BOINC (Berkeley Open Infrastructure for Network Computing) software to process and send data. BOINC is a system for volunteer computing (a type of distributed computing) developed originally to support the SETI@home project which later became the platform for many other applications. SÚRO tested both the BOINC Manager with graphical user interface and “boinctui” application running in the command line.

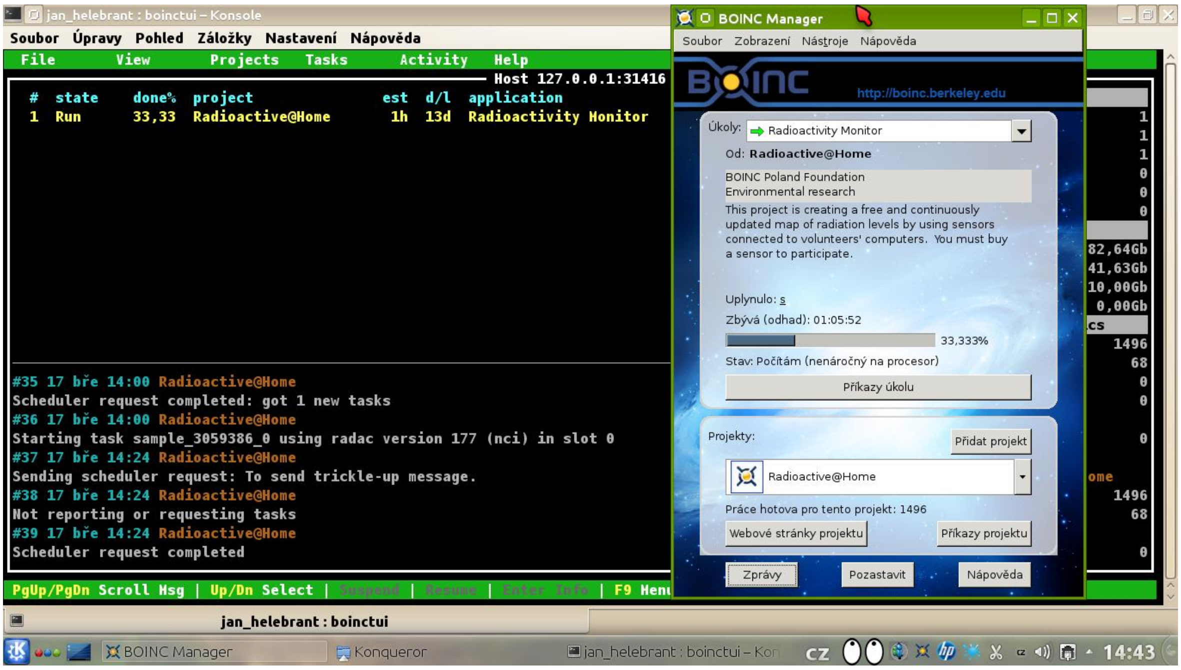

Figure 24. Radioactive@Home detector software.

Data received from the sensor network was presented in the form of an interactive map with a clear color display according to the measured values - green dots - dose rate up to 0.3 µSv/h, yellow dots - dose rate in 0.3-0.8 µSv/h range, red dots - dose rates above 0.8 µSv. After clicking on a specific detector, a graph of values and other details are available.

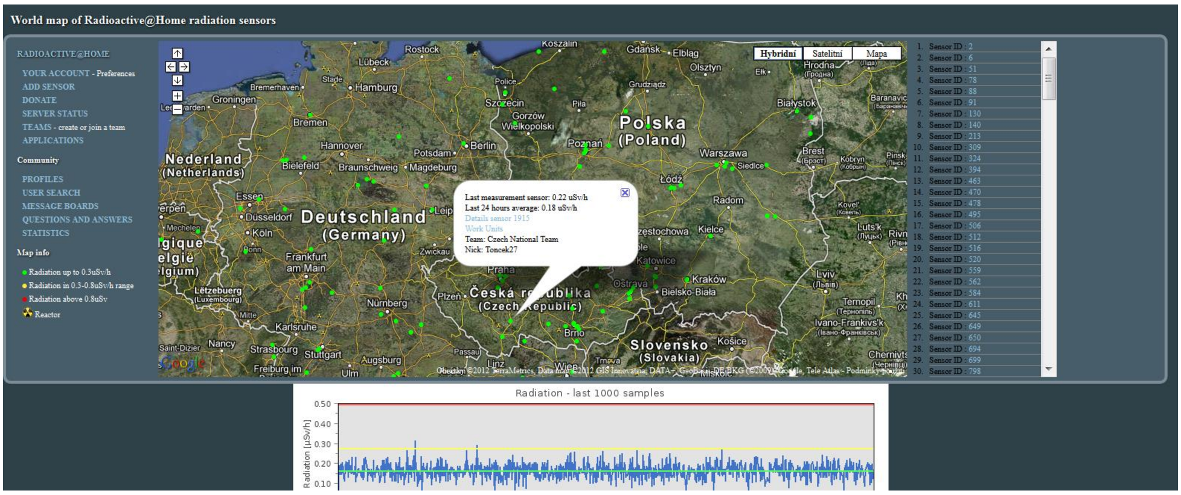

Figure 25. Radioactive@Home online map.

The project faced problems in 2025, and the map (although still available) does not currently display any detector data.

2.3 Follow-up citizen-science projects

The great potential of citizen radiation measurement has also been recognized by many professional institutions - both institutions in the field of radiation protection and various commercial companies.

RAMESIS and CzechRad projects (Czechia)

The National Radiation Protection Institute (SÚRO) became interested in citizen radiation measurements in 2011 after the Fukushima nuclear power plant accident in Japan, and after pilot tests of various devices, SÚRO purchased the Safecast bGeigie Nano detector in 2015 and became involved in measuring and supplying data to the public Safecast database.

Figure 26. Safecast bGeigie Nano (left), RAMESIS fixed station (right)
(photo by Jan Helebrant, CC BY-SA, Flickr.com)

As a part of the project "Radiation Monitoring Network for institutions and schools to assure early awareness and enhancing safety of citizens" (RAMESIS, 2015-2019, https://starfos.tacr.cz/en/projekty/VI20152019028) within the Security Research Programme of the Czech Republic provided by the Ministry of Interior of the Czech Republic, the number of bGeigie Nano detectors was gradually increased to approximately 60. The detector users included the general public incl. students as well as professionals from the State Office for Nuclear Safety or first responders.

An important part of the project was the ability to view data without having to upload it online. A custom-developed Safecast plugin, now Radiation Toolbox, was created for the years-proven free program QGIS. Thanks to this plugin, it was possible to load data from Safecast devices and later from CzechRad directly into QGIS. In this way, the user could check the measured data before uploading it online and possibly delete some of the data. When using offline base maps, it is possible to work completely without an internet connection.

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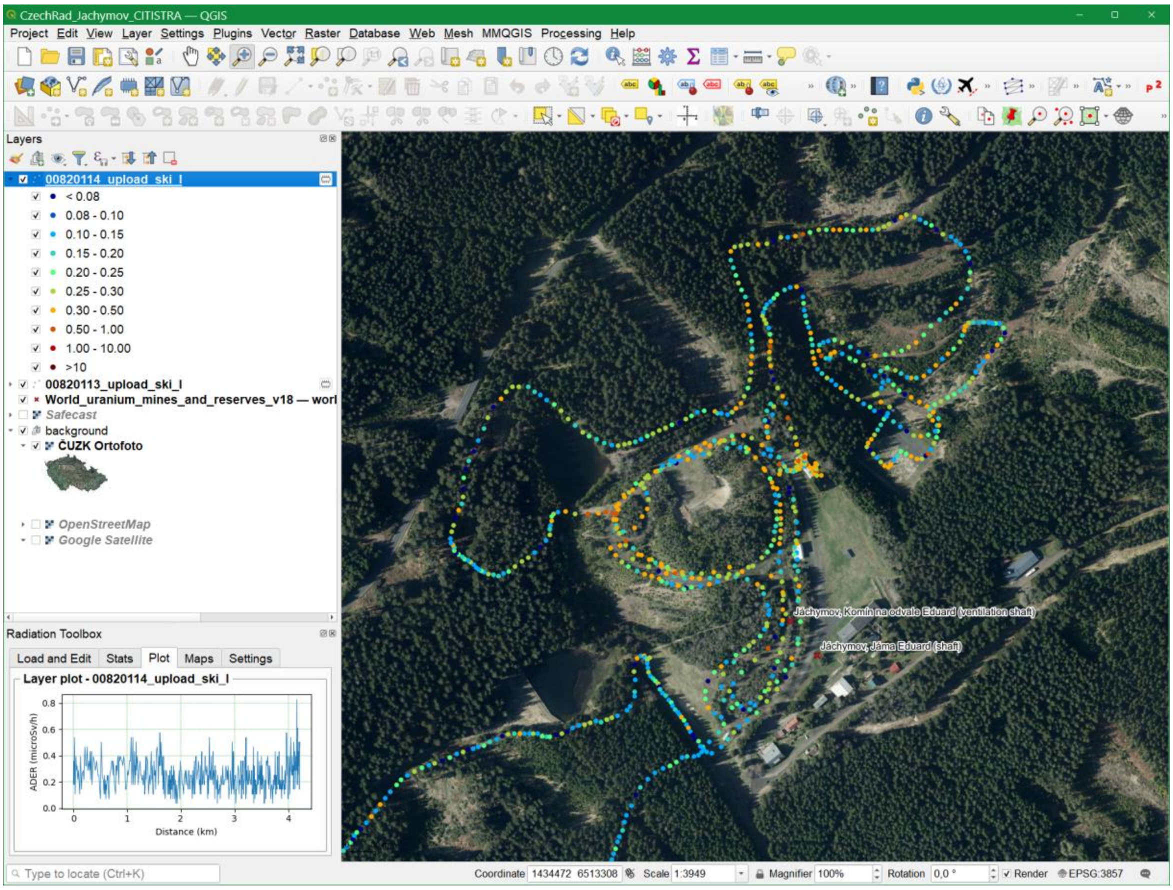

Figure 27. Open-source QGIS program with custom-developed Radiation Toolbox plugin

New stationary stations for online radiation measurements have been also developed in the frame of this project. The stations included a detection unit based on a plastic scintillator measuring 18 x 15 x 10 mm^3 with a silicon photomultiplier (SiPM), and an ARM platform microcomputer with the GNU/Linux operating system was responsible for data processing and sending to the SÚRO server. The user could see the dose rate values on the LCD display on the station and also in the online application. The station connected to the Internet via an Ethernet cable plugged into a regular router.

An integral part of the project were also various educational activities, workshops with students, and also an information portal - now CzechRad Wiki (www.suro.cz/aplikace/czechrad-wiki/, only in Czech).

The discontinuation of production of the bGeigie Nano device in 2020 and SÚRO's efforts to provide an alternative solution led to the development of the CzechRad detector (https://github.com/juhele/CzechRad) as a part of the project "*Center for the support of the population in case of actual or suspected occurrence of extraordinary nuclear and radiation events*" (IMPAKT, https://starfos.tacr.cz/en/projekty/VJ01010116, 2021-2025) provided by the Ministry of Interior of the Czech Republic.

Figure 28. CzechRad detector during the field measurements (photo by Marie Davídková, CC BY-SA, Flickr.com)

Although the CzechRad device does not differ much from the SAFECAST bGeigie Nano device at first glance, the internal electronics are completely different. The data format from the CzechRad device is the same type as that used by SAFECAST and is therefore compatible with existing software tools and the SAFECAST online infrastructure. A detailed description of the CzechRad instrument will be provided in the CITISTRA document *"CzechRad detector parameters, acquisition and use of data"* (Deliverable D9.2). Thousand of CzechRad devices were manufactured within the IMPAKT project, another 300 were manufactured in the frame of CITISTRA project.

OpenRadiation (France)

The Openradiation platform (www.openradiation.org) was created in France after 2016 as a result of cooperation between the IFFO-RME educational institute, the Radioprotection and Nuclear Safety Institute (Institut de Radioprotection et de Sûreté

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Nucléaire, IRSN), the non-profit organization PLANETE SCIENCES and the Sorbonne Université of Paris.

The website tries to focus on both ground and aircraft measurements, etc., all measured data can be downloaded under the Open Data Commons Open Database License (ODbL).

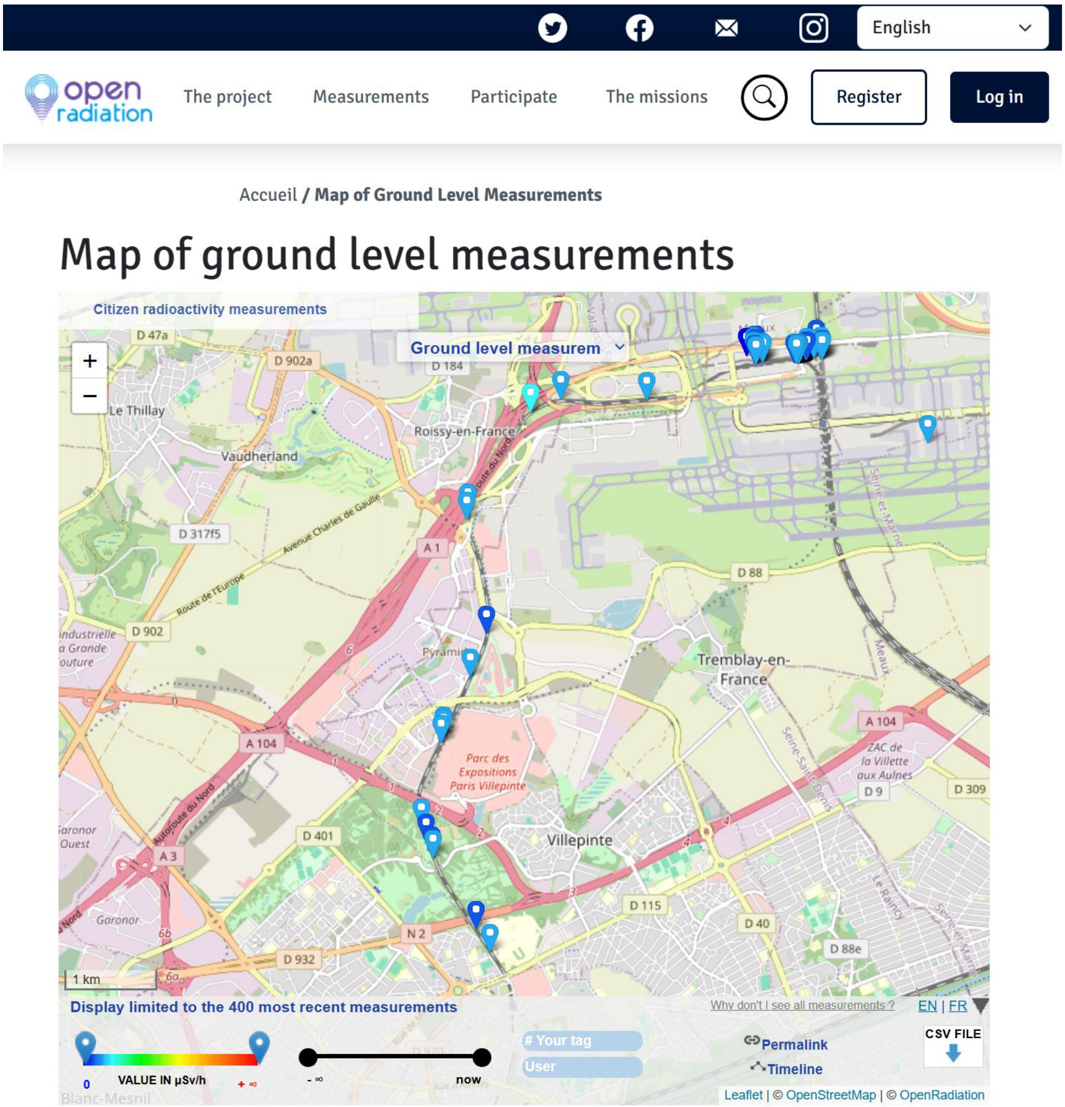

Figure 29. OpenRadiation map (source: www.openradiation.org)

The project also developed its own detector based on the proven SBM-20 GM tube communicating with a smartphone and the OpenRadiation application. The system should also support other types of devices, including Safecast bGeigie Nano with Bluetooth module, or French RIUM devices.

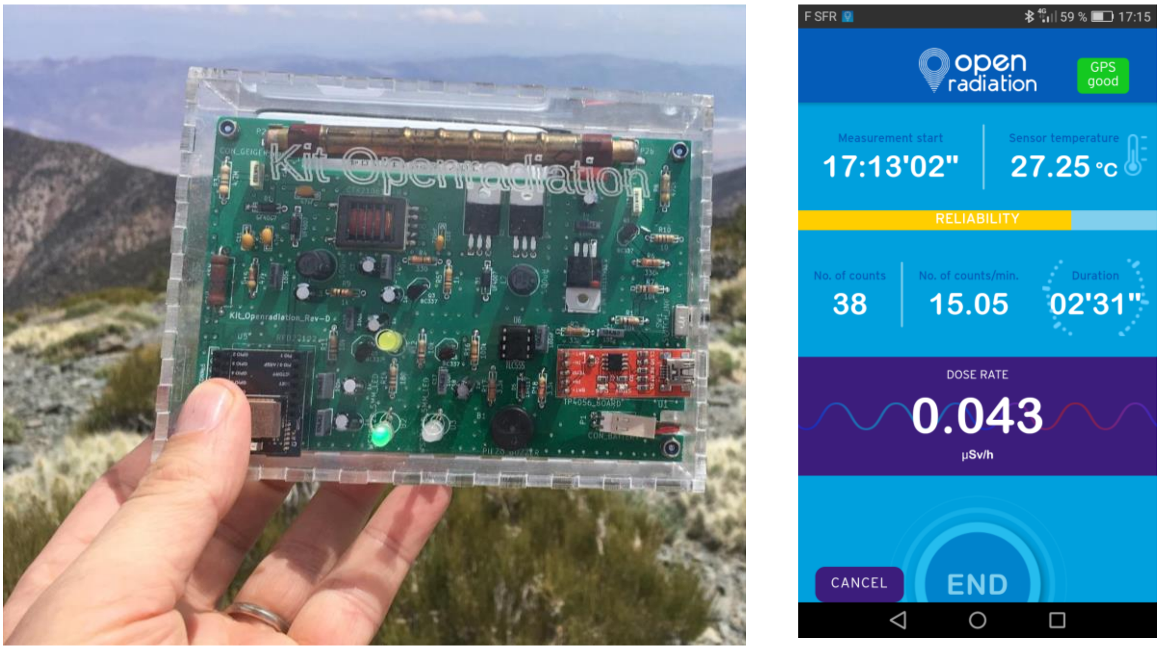

Figure 30. OpenRadiation detector (kit) (left, source: www.openradiation.org) and Android application (right, source: Google Play store)

Like most citizen radiation measurement projects, it uses a non-GPS detector, communicating mostly wirelessly with an Android or iOS smartphone. This allows for simpler detector hardware (especially for GM-based detectors) - a smartphone is used to display values, process/send data, and as a source of GPS data. The disadvantage of these solutions is the need to maintain an up-to-date mobile application and the dependence on wireless communication, which can be a security risk in the event of armed conflicts.

SaveDnipro

The NGO "SaveDnipro" was founded in Ukraine in 2020 and focuses its activities on protecting citizens' rights to a clean and safe environment, promoting the implementation of environmental reforms, and disclosing socially important environmental information.

SaveDnipro operates the SaveEcoBot system, including an environmental chatbot and aggregating various environmental data into interactive maps (air quality, background radiation, fires, and water quality) (https://www.saveecobot.com/en).

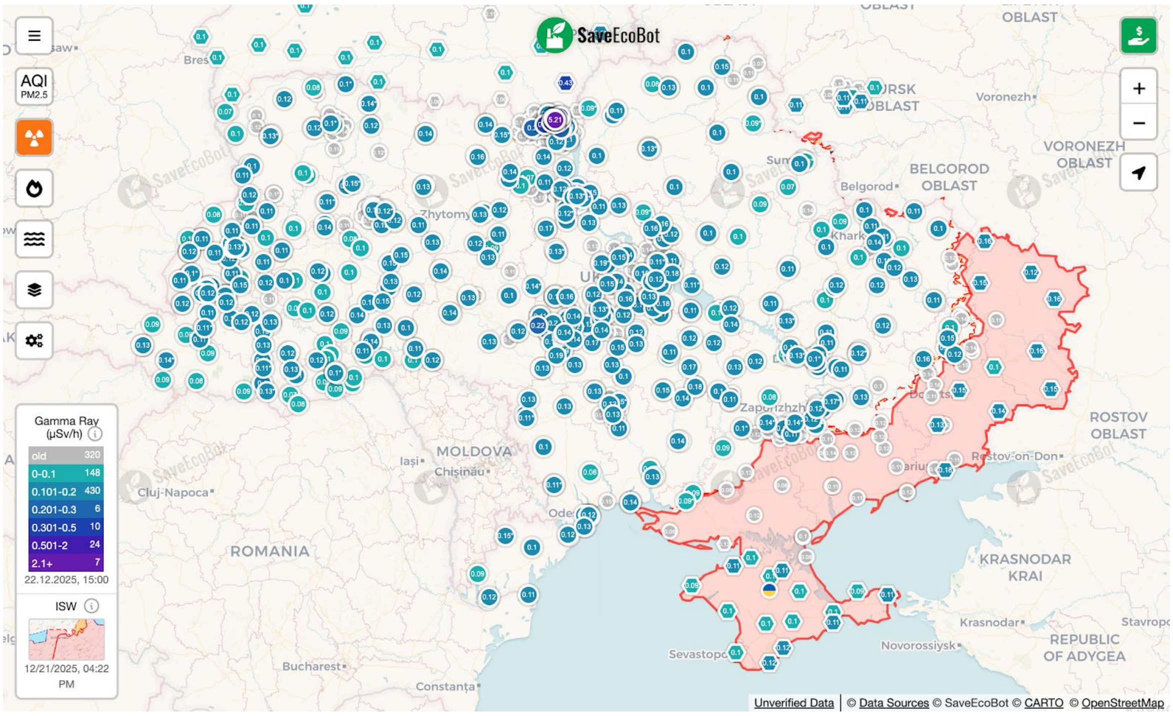

Figure 31. SaveEcoBot radiation map in Ukraine

After the start of Russia's invasion of Ukraine in February 2022 and especially after the occupation of the Chornobyl exclusion zone by the Russian army, SaveDnipro added a radiation layer to the SaveEcoBot map (https://www.saveecobot.com/en/radiation-maps), to which measuring stations from various sources were gradually added - official sources such as Data provided by the Ukrainian Hydrometeorological Center (Український гідрометеорологічний центр), Main Center of Special Monitoring (Головний центр спеціального контролю) or State Specialized Enterprise "Ecocenter" (Державне агентство України з управління зоною відчуження). Later, measuring stations from the EURDEP network were also added (EUropean Radiological Data Exchange Platform). Following the increased interest in information about radiation levels in Ukraine, the SaveEcoBot map was later translated into many other languages. Until now, no such comprehensive radiation map existed.

Following the unprecedented and dangerous actions of Russian troops at Ukrainian nuclear facilities (including the Chornobyl Nuclear Power Plant (CHNPP) and the Zaporizhzhia Nuclear Power Plant (ZNPP)), SaveDnipro joined forces with Safecast, Czech National Radiation Protection Institute (SÚRO), and the Chornobyl Radiation Ecological Biosphere Reserve (Чорнобильський радіаційно-екологічний біосферний заповідник).

The result was the #bgeigies4ukraine initiative (already described in more detail in the previous section about Safecast), within which 10 Safecast bGeigie Nano devices were delivered to Ukraine from Czechia. Invading troops left the Chornobyl area on March 31, 2022, and the first post-invasion Safecast data from the zone was published on May 3rd.

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Figure 32. A #bgeigies4ukraine bGeigie Nano in the field (photo by Pavlo Tkachenko, SaveDnipro)

Other SaveDnipro activities in the field of radioactivity include educational activities (detectors in schools) or - in cooperation with Safecast (again described in the previous section) the installation of stationary Radnote stations within the SaveEcoBot network.

Žhavá Místa, Czechia

Žhavá Místa (in English: "Hot Places", www.zhavamista.cz) project is an initiative of "radioactivity enthusiasts" that began around 2020 and in September 2025 a "registered association" was formally established according to the Civil Code of the Czech Republic.

The association brings together people interested in radioactivity, owners of radiation measuring devices and other interested persons. The project also cooperates with organizations such as SÚRO, Safecast, uRADMonitor, ÚJV Řež (Nuclear Research Institute in Řež), Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University in Prague) etc.

Their interactive web map brings together data from various types of measurements (in-situ, walking/driving) from various devices (Safecast, CzechRad, Radiacode, Raysid, etc.).

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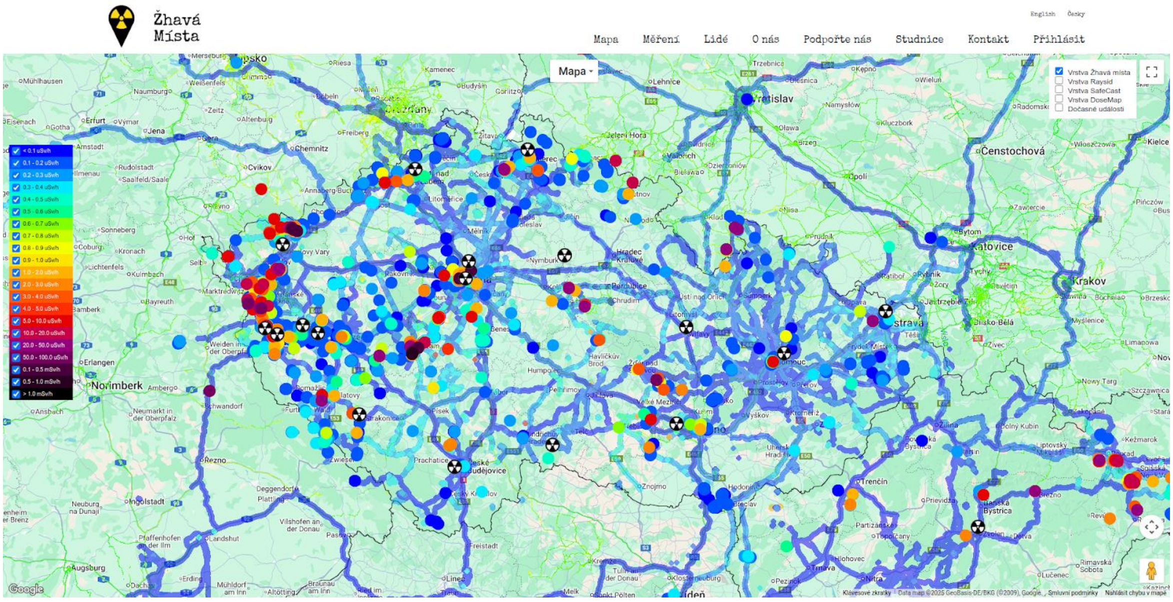

Figure 33. Žhavá Místa - interactive map (https://www.zhavamista.cz/mapa)

Since February 2024, after negotiations with SÚRO, the Žhavá Místa project has gradually taken over the management of the stationary radiation measurement stations from the RAMESIS project, which SÚRO could no longer operate due to increased IT security requirements. Other stationary stations in their network are uRADMonitor stations.

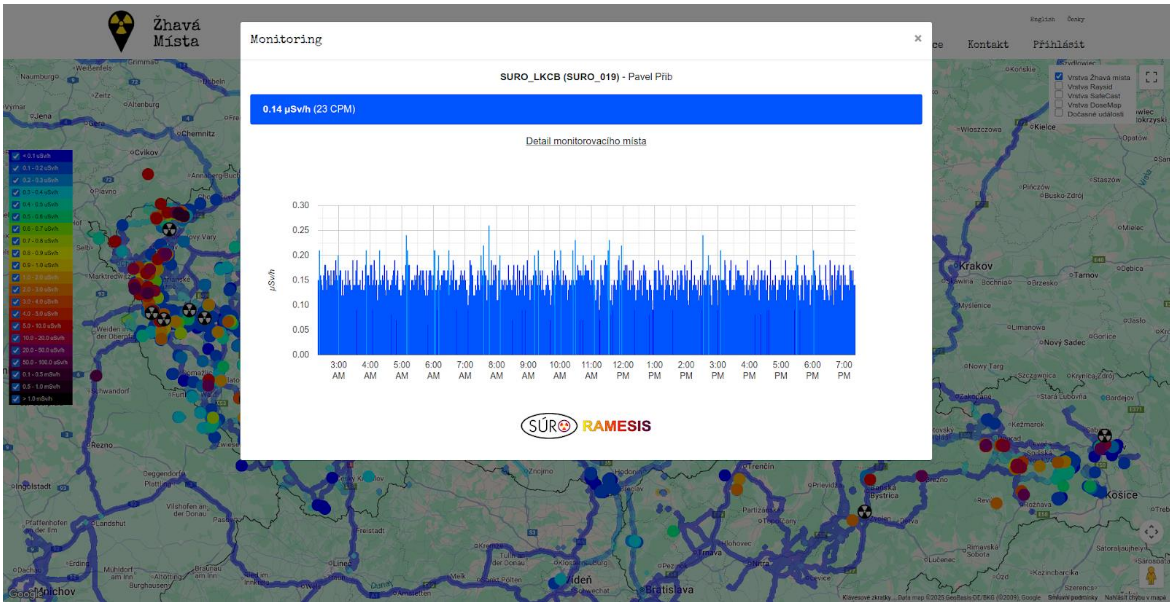

Figure 34. Žhavá Místa - detail of fixed station data (https://www.zhavamista.cz/mapa)

The group is also active on social networks (Twitter/X, Facebook, Instagram) with posts focused on education in the field of radioactivity, radiation protection and radiation

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measurements, including the fight against fake news in the field of radiation. Also runs a discussion community on the Discord platform.

Other

Other projects include, for example, the Spanish company Libelium (www.libelium.com), which started to offer a solution called "Waspmote" based on the Arduino-like microcontroller and expansion modules (so-called shields) with a GM detector, the Romanian project uRADMonitor (www.uradmonitor.com) offering several types of stationary stations for online radiation and air quality measurements.

Some manufacturers of professional radiation detectors also had the option of displaying data on a map - Belarusian Polimaster, Ukrainian Ecotest. The Russian manufacturer of the popular pocket spectrometer RadiaCode also offers its own online map - RadiaVerse (https://map.radiaverse.com/).

Other examples of projects are the Russian Dosemap (https://dosemap.org) or the Spanish OpenRed (https://map.open-red.es) using data from various existing 3rd party produced detectors.

3 Legal framework in case of radiation emergency in each country

3.1 Czechia

The Czech Republic has a well-developed system for managing radiation extraordinary events (RMU), covering everything from minor radiation incidents to severe radiation accidents that could affect the public.

The current framework is based on the Atomic Act of 2016, which replaced the 1997 law and introduced unified terminology ("radiation extraordinary event management"). It aligns with IAEA standards and EU requirements. The National Radiation Protection Institute provides expertise, conducting risk assessments and developing guidelines.

Nuclear installations and workplaces with significant radiation sources are divided into five threat categories (A to E):

- Category A: nuclear power plants
- Category B: other nuclear reactors and certain high-risk (category IV) workplaces where a radiation accident is possible
- Category C: lower-risk nuclear facilities or workplaces where an accident cannot occur
- Category D: transport, lost/stolen sources, dirty bombs, or other activities that could cause accidental exposure outside fixed sites
- Category E: areas in Czech territory potentially affected by an accident abroad

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The basic document for large-scale or cross-regional events is the National Radiation Emergency Plan (NRHP)[45]. It covers situations where a radiation accident occurs:

- outside the pre-defined emergency planning zones around nuclear power plants, or
- anywhere in the country (including transport accidents, terrorist use of radioactive material, orphan sources, etc.), or
- abroad but with consequences reaching Czech territory

The NRHP applies mainly to serious events that may require protective actions for the public beyond a single region or beyond the normal emergency planning zones. Such events can range from local incidents (managed by a single region) to nationwide emergencies that require declaration of a state of emergency and activation of the Central Crisis Staff. Crisis states - ranging from a state of danger to a state of war - can be declared under the Crisis Act to mobilize resources.

The plan also includes strategies for the recovery phase - when the emergency exposure situation turns into an existing exposure situation - with emphasis on optimisation of radiation protection and return of affected areas to normal use.

The **State Office for Nuclear Safety**, in cooperation with the **Ministry of the Interior**, is responsible for developing and updating the NRHP. The plan complements, but does not replace, the existing on-site and off-site emergency plans for nuclear power plants and the general crisis plans of regions and the Integrated Rescue System (IZS).

Radiation monitoring [46] in response to a radiation event is carried out through 25 professional mobile groups (SÚRO, SÚJB, firefighters, police, customs officers, Czech Army, ČEZ - operator of Czech nuclear power plants) for ground-based radiation monitoring and 2 airborne groups (SÚRO, Czech Army) for airborne radiation monitoring. Every three years, a joint exercise of these groups is held in the emergency planning zone of one of the two Czech nuclear power plants in response to a fictitious radiation accident at the power plant. Technical means for decontamination of equipment and people are available to specialized units of the fire department and the Czech Army.

3.2 Slovakia

Crisis management bodies in the Slovak Republic deal with the management of processes related to crisis resolution.

The Crisis management bodies are:

- Government of the Slovak Republic, Security Council of the Slovak Republic
- Ministry and other central state administration bodies
- National Bank of Slovakia
- Regional Security Council
- District Office
- District Security Council
- Municipality

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The executive body of the crisis management body is the crisis staff (headquarters). The crisis staff is not a permanent body, it is activated only in the event of an imminent danger of a crisis situation or when a state of crisis is declared, and it operates only temporarily. The government establishes the “Central Crisis Staff” (chaired by the Minister of the Interior of the Slovak Republic) in case of emergency exceeding the area of the region.

The essential dividing of the competences of ministries and other central state administration bodies concerned with emergency preparedness are covered in the Act No. 575/2001 Coll. on the organisation of government activities and the organisation of central state administration.

The decisive competences in the field of emergency planning and emergency response are vested in the **Ministry of Interior of SR.**

It has the central role in the state administration in the field of the Integrated Rescue System, civil protection and fire-fighting protection, in the field of ensuring the activities of the central crisis headquarters and in the field of coordinating the performance of state administration carried out by municipalities, higher territorial units and local state administration bodies.

The conditions for ensuring the protection of life, health and property against the consequences of emergencies, the roles and responsibilities of state administration bodies, municipalities and the rights and obligations of natural persons and legal entities in ensuring the civil protection of the population are laid down by the Act No. 42/1994 Coll. on Civil Protection of the Population.

Ministry of Health of SR is the central government authority for health care and health protection. The protection of public health in the field of radiation protection is guided and controlled by the public health authorities.

The requirements for emergency preparedness for activities leading to exposure and for the protection of the health of workers and the general public against ionising radiation in emergencies, are regulated mainly by:

- Act No. 87/2018 Coll. on radiation protection and on amendments to certain laws, which is transposing the European directive No. 2013/59/EURATOM.
- Decree of the Ministry of Health of SR No. 96/2018 on details of radiation monitoring network.

The central state organ for radiation protection is the Public Health Authority of Slovak Republic (PHA SR) and practical state administration in an area of radiation protection is covered by selected regional public health authorities – in Bratislava, Nitra, Banská Bystrica and Košice.

Regarding the emergency preparedness and response are their competences given as:

- monitor of the radiation situation in the environment in Slovakia, ensure the activities of the central radiation monitoring network and inform the European Union institutions about the radiation situation in the Slovak Republic,

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- participate in the resolution of emergency situations in the event of loss of control over sources of ionising radiation and in the event of discovery of sources of radiation of unknown origin,
- propose the implementation of protective measures in the event of a threat to public health,
- provide information to the public on the radiation situation, threats to public health and possible exposures.

The central government authority for nuclear installations is the **Nuclear Regulatory Authority of the Slovak Republic**. The Emergency Response Centre (ERC) is established at the Nuclear Regulatory Authority of the Slovak Republic to assess the course and consequences of incidents and accidents at major nuclear installations in terms of their potential impact on the environment, to prepare proposals for protective measures or recommendations for further action and to carry out exercises.

Monitoring of a radiation situation is performed according to the above-mentioned decree on details of the radiation monitoring network (RMN). According to the decree the RMN basic components are the Monitoring Network Headquarters (at the PHA SR), permanent and emergency parts.

The early warning network (permanent part of RMN), which consists of a system of monitoring points for continuous measurement of ambient dose equivalent rate on the territory of the Slovak Republic for immediate notification of its increase above the level of natural radiation background, was established at the Slovak hydrometeorological Institute (SHMÚ) as organization designated by the Ministry of the Environment of the Slovak Republic. (https://www.shmu.sk/sk/?page=20)

SHMÚ Radiation Monitoring Network consists of the probes RPSG-05 from Microstep-MIS, s.r.o. (5 pcs), EcoGamma-G from Canberra-Packard (5 pcs) and EGM-04 from NUVIA (20 pcs), which are deployed at 30 points - professional meteorological stations, airports and automatic meteorological stations throughout Slovakia.

The probes are based on a pair of GM detectors and are placed at a standard height of 1 m above the terrain and connected to the SHMÚ data network. They provide data in an interval of 1 min.

The map of localities and the measured data are publicly available on the web of SHMÚ – at the address https://www.shmu.sk/sk/?page=1&id=radioaktivita for the last 30 days.

Another early warning network for radiation situations within the competence of the Crisis Management Section of the Ministry of the Interior (hereinafter referred to as the "SVVRS MV SR") is formed by a system of monitoring points for continuous measurement of the dose equivalent of gamma radiation from the air in the territory of the Slovak Republic for immediate notification of its increase above the level of natural radiation background. The network consists of 23 monitoring stations for measuring the spatial dose equivalent of gamma radiation from the air in nSv/h in a fully automated continuous mode. The monitoring stations are physically installed on the structure of selected electronic sirens.

The station itself consists of an intelligent probe type NuDET EMG-2 with two G-M tubes with different sensitivities, which covers the probe's measurement range from 50 nSv/h to 2 Sv/h, and control electronics, which ensures its own measurement and subsequent sending of measured data in the form of 10-minute averages to the central workplace.

The map of the measuring points is available at the web of the Ministry of Interior of the Slovak Republic at https://www.minv.sk/?Civilna_ochrana in section "Protiradiačné opatrenia". The measured data are not publicly available.

At the NPP Jaslovské Bohunice the atmospheric emissions and hydrosphere effluents are regularly measured and evaluated in the 15-km area around the plant. There are 24 monitoring stations of a teledosimetry system, which continuously monitor dose rate of gamma radiation, volume activity of aerosols and radioactive iodine in the air. The map of the monitoring points is available at the web of Slovenské elektrárne (Slovak Power Plants) in section "Environment" https://www.seas.sk/en/elektraren/npp-bohunice/

At the NPP Mochovce Atmospheric emissions and hydrosphere effluents are regularly measured and evaluated in the 15-km area around the plant. There are 40 monitoring stations (19 on site and 21 off-site) of a teledosimetry system (map at the https://www.seas.sk/en/elektraren/mochovce-nuclear-power-plant/).

Moreover, samples of soil, ground water and food chain (feed, milk, agricultural products) are regularly analysed, too. The volume of radioactive substances contained in liquid and gaseous discharges is considerably lower than the limits set out by authorities. Monthly reports of releases into the environment should be according to the information on the web pages available in the section Publications, but they cannot be found there.

The Public Health Authority of the Slovak Republic and the selected regional public health authorities (in Banská Bystrica, Nitra, Košice, Bratislava) are performing integral measurements using thermoluminescent dosimeters at 56 monitoring sites in the Slovak Republic. The measured data are not publicly available. Part of the information is available in a weekly reports on radiation situation at the web of PHA SR at the https://www.uvzsr.sk/web/uvz/aktualne-informacie-a-oznamenia.

3.3 Poland

In Poland, in case of a radiological event on national scale, the cooperation between authorities and services involved in eliminating such incidents and addressing their effects is defined in the Atomic Law and in the Regulation of the Council of Ministers of May 25, 2021 on emergency plans in the event of a radiation emergency (Journal of Laws of 2021, item 1086). This regulation specifies in detail the scope of the provincial emergency plans (plan postępowania awaryjnego, PPA). Based on these regulations and an analysis of potential threats and their possible scenarios, each head of an organizational unit and the voivode develops a PPA, which will be implemented in the event of an emergency, limited to the organizational unit or the voivodeship (Voivodeshaft Crisis Management Centre), respectively. The national emergency plan for threats of national scope is developed by the minister responsible for internal affairs and then agreed upon with the President of the PAA (Państwowa Agencja Atomistyki - the National Atomic Energy Agency) and the minister responsible for administration. In the event of an emergency, the CEZAR Center for Radiation Emergency (Centrum Zdarzeń Radiacyjnych CEZAR) of the PAA participates in assessing the national radiological situation. It utilizes computer-aided decision support systems to forecast

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and analyze the country's radiation situation. The center also assesses the risk to the population and the environment in the event of a nuclear power outage, based on information obtained from a network of measurement stations, meteorological data, and international partners. PAA is also implementing the Computer Data Analysis Center (CDA), which will assist in the ongoing assessment and analysis of the country's radiological events.

In Poland, the crisis management system for radiological emergencies is governed by the Act of 26 April 2007 on Crisis Management and coordinated through the National Crisis Management System, which integrates various levels of government and emergency services. It specifies the bodies and principles of operation in the crisis management system in Poland, defining crisis actions as prevention, preparation, response, and recovery from crisis situations (threats that do not justify states of emergency), in order to protect people, property, and the environment. The act defines the structure, competencies, and tasks of public administration bodies (central and local government) at the central and local levels of management.

The Act of December 5, 2024, on Population Protection and Civil Defense (Journal of Laws 2024, item 1907) introduces a comprehensive and coherent system of population protection in Poland, defining tasks, authorities (from central to local), and principles of preparedness for crisis situations (natural, technical, military) through planning, building public awareness, creating warning systems, and modernizing shelter facilities. This constitutes a fundamental reform of the country's security. It (i) defines the responsibilities of the state, local governments, and citizens in emergency situations, the roles and responsibilities of various institutions for the implementation of tasks, (ii) standardizes systems for notification, warning, and alerting about threats (e.g., sirens, RCB Alerts), (iii) introduces a classification of collective protection facilities, principles for their registration, use, and modernization, (iv) emphasizes building public awareness and preparing citizens for action and (v) establishes principles for financing activities related to civil protection.

The Government Security Centre (Rządowe Centrum Bezpieczeństwa, RCB), under the Ministry of Interior and Administration (Ministerstwo Spraw Wewnętrznych i Administracji, MSWiA), serves as the central coordination body, ensuring preparedness, response, and recovery. This center uses the GSM system to send SMS messages to all recipients throughout the country or a given region, warning about potential threats. The first responder framework includes the State Fire Service (Państwowa Straż Pożarna PSP), emergency medical services, police, and specialized units like the Chemical, Biological, Radiological, and Nuclear (CBRN) response teams, operating under the Ministry of Interior and regional voivodes (wojewodzi - governors).

The State Fire Service (Państwowa Straż Pożarna) with its nationwide network of professional and volunteer units, is the primary responder for radiological incidents, equipped with specialized detection equipment and personal protective gear. The National Atomic Energy Agency (PAA) provides technical expertise, monitoring radiation levels and advising on protective measures, in line with the International Atomic Energy Agency (IAEA) standards. The Early Warning and Notification System employs sirens, mass media, and mobile alerts to inform the public, with predefined protocols for radiological emergencies, including sheltering and evacuation plans developed at the voivodeship and municipal levels.

Crisis management operates across four phases-prevention, preparedness, response, and recovery-with detailed plans outlined in National and Voivodeship Crisis Management Plans.

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Local governments, led by mayors or county heads, initiate immediate response actions, supported by regional and national resources when needed. Poland emphasizes international cooperation, participating in EU and NATO exercises and maintaining bilateral agreements with neighboring countries for cross-border radiological incidents. Regular training, simulations, and public awareness campaigns, supported by projects like the EU's radiological preparedness initiatives, enhance the system's effectiveness in protecting populations and responders. Recently "Be Ready" (Bądź Gotowy) safety guide, officially titled the "Guide for Crisis and War" a government-issued booklet and online resource was distributed. It provides instructions for citizens on preparing for and responding to various emergencies, including war, natural disasters, power outages, and disinformation, with advice on creating emergency kits, understanding alarm signals, evacuating, and protecting against threats like chemical attacks. Distributed to every household, it emphasizes preparedness for potential conflict, power cuts, and extreme weather, offering actionable tips from the Government Centre for Security (RCB).

4 Possible implementation of the citizen radiation measurements into the legal framework

4.1 Introduction

Radiation emergency preparedness and response rely on timely, accurate, and spatially resolved environmental monitoring data. Official monitoring networks, while robust, may have limited spatial density, particularly in residential or rural areas. Citizen-based radiation measurements can serve as a supplementary component to official radiological monitoring systems during a radiation emergency including war or armed conflicts situations or natural disasters. Advances in portable radiation detectors and digital communication platforms enable now to collect and share radiation measurement data at unprecedented scales. The citizen measurements of gamma-rays dose-rates can be performed by non-expensive radiometers based on Geiger-Mueller tubes, which are sensitive enough to detect even relatively small (by factor 2-5) increase of natural gamma-rays background. The primary purpose of such measurements is to enhance spatial and temporal resolution of environmental gamma-dose rates, support early detection of localized anomalies, and improve communication between authorities and affected populations.

European radiation protection culture is highly conservative by design, prioritizing reliability and legal clarity. Many potentially simple concepts like e.g. dosimetric passports for radiation workers are still not implemented within the European Community. The Basic Safety Standards (BSS) Directive enforces a high degree of consistency in radiological protection regulations at the European level. Regulations almost always require calibration of instruments, quality assurance of procedures, qualification of personal and traceability. Those requirements are practically impossible to be fulfilled in the large-scale citizen measurements. Therefore, it would be difficult for national regulators to include citizen science as a serious partner in case of radiation emergency situations.

Despite all those difficulties, citizen science in Europe will grow in the future because of the growing self-organization of modern society, as well as the increasing role of social

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media. Members of the society want to take advantage of their growing education level and technical skills, to be prepared to verify official data. Regulators, despite the rigid current frames, have to learn how to take advantage of this growing potential.

The primary scientific contribution of citizen radiation monitoring data lies in enhancing spatial and temporal data resolution, supporting rapid identification of localized anomalies, and strengthening transparency and public engagement. Future work should focus on standardized protocols, validation methodologies, and formal integration into national and international emergency preparedness frameworks.

4.2 Previous experiences on using citizen measured data by authorities

(i) Japan

Safecast was created by citizens very soon after the 2011 Fukushima accident, largely because people distrusted the availability and transparency of official radiation data. Citizens felt government monitoring networks were too sparse and not publicly accessible in usable form, so volunteers started independently mapping radiation levels across Japan. In the early months after the accident, Japanese authorities did not officially recognize or integrate citizen measurements into formal radiation protection reporting. In fact, some government officials publicly advised people to rely only on official government data, not on independent measurements like those from Safecast. [47]

Over time, some local municipal governments in Fukushima began cooperating with Safecast. In cities such as Minamisoma, Tamura, and Koriyama, local authorities worked with Safecast volunteers to conduct detailed “street-by-street” dose rate surveys using Geiger counters provided by Safecast. These efforts were aimed at creating more comprehensive maps than the limited official monitoring networks could offer. In these cooperative cases, Safecast data were used to provide additional local environmental information that helped municipal officials and local communities better understand spatial variations in radiation levels.

Despite the fact that the Safecast data were not formally adopted into the national regulatory radiation protection system e.g., as official dose assessments for evacuation planning or regulatory compliance, researchers and some local authorities recognized the scientific value of Safecast data. Several studies have shown that the large Safecast dataset correlates reasonably well with official measurements, indicating it can be a valuable supplementary source for environmental radiation monitoring [48]. International technical evaluations, such as in IAEA-related reports, note that Safecast conducted extensive volunteer surveys and that these data can augment understanding of contamination patterns, especially at fine spatial scales not captured by official networks [49]. National-level authorities remained cautious about directly using citizen-generated radiation data in official decision-making, partly because of quality assurance concerns (training of volunteers, instrument calibration) [50].

Figure 35. Radiation hotspot in Kashiwa, Japan, February 2012;
By Abasaa - Own work, Public Domain, Wikimedia Commons

(ii) Czech Republic

In Czechia the collaboration between authorities and citizen measurements of radiation levels was developing very smoothly thanks to the RAMESIS and CzechRad projects [see chapter 2.3]. Within the RAMESIS, dedicated to institutions and schools in the Czech Republic, 60 bGeigie Nano detectors were distributed to students, professionals from the State Office for Nuclear Safety and first responders. The measurement data were verified before uploading thanks to the Radiation Toolbox, which allows to check the measured data. Initially, the authorities were distrustful of the data obtained in this way - especially when it came to various "Do it yourself" (DIY) devices. However, pilot tests with SAFECAST bGeigie Nano devices demonstrated very good results and SÚRO's activities in this field also gained the attention of the national nuclear authority - State Office for Nuclear Safety.

Within the framework of the aforementioned projects, SAFECAST and CzechRad detectors were used by first responders (firefighters, police) and SÚJB employees. So far, there has been no formal problem with the publication of measured data from the aforementioned users - although in some cases the user's name was not published, but instead, for example, the name of the organization has been used.

Czech legislation does not explicitly prohibit the use of "citizen detectors" by common citizens or professionals like first responders and in the latter case, unless the internal

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regulations of individual organizations forbid it, these results can also be shared with the public (possibly with some disclaimer). However, because these devices are not metrologically verified, formal decisions like protective measures (evacuation / shelter, etc.) - cannot be made based on the results. Nevertheless, if a location is found to have "dangerous levels" of radiation, the police or firefighters may, even on the basis of citizen measurements, temporarily fence off the area or prevent public access. Professional measurements will then be carried out by radiation specialists.

4.3 Limitations of the citizen measured data

The concept of citizen science is usually not reflected in legislation unless the activity in question conflicts with existing legislative regulations. Various types of ionizing radiation detectors are freely available on the market - from inexpensive GM tube-based ones to sophisticated devices with scintillation crystals and the ability to perform spectrometric measurements. However, the willingness to implement data from citizen radiation measurements in some way by official institutions/organizations involved in crisis management/emergency preparedness is limited by several factors:

1. **Data quality**

There are several factors, which can influence the quality of data collected within the citizen measurements:

(i) Energy, angular and dose rate response of the dosimeters.

Low-cost devices are generally not type-tested; therefore, their response can strongly depend on radiation type, dose rate, energy, and measurement direction. Morosh et al. [51] investigated the metrological performance of 16 different inexpensive dose-rate detector models (68 units in total) commonly used in non-governmental and citizen-science monitoring networks. The performance parameters analyzed included inherent background, energy dependence, linearity of response, sensitivity to small changes in dose rate, and stability under varying climatic conditions (temperature and humidity). The authors concluded that one of the most serious limitations of low-cost detectors is their strong energy dependence (up to a factor of 6.7), which significantly affects measurement accuracy under varying radiation energy spectra. The use of this type of detector is therefore much more appropriate when a large number of identical devices are available, allowing some form of collective "type testing" to be performed.

(ii) Individual calibration

Citizens usually do not have access to professional calibration services for radiation detectors. Over time, the calibration coefficients of these devices may change significantly due to alterations in detector properties. However, even inexpensive detectors can exhibit surprisingly good long-term stability. In particular, the Geiger–Müller tubes used in the

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Safecast network have been in operation for many years and have demonstrated good stability of calibration factors over long-term use.

(iii) Training

The quality of data collected by citizens strongly depends on the education and training of the individuals performing the measurements. Factors such as the timing of measurements, distance from the source, detector contamination, and insufficient power supply can all affect data quality. Therefore, some level of education and training—such as through online tutorials—should be made available, as demonstrated by initiatives like the CITISTRA project.

2. Data quality control

It is absolutely necessary to ensure some control of the data before it is published. There are several reasons - malfunctioning equipment, false hotspots (e.g. a detector user meets a patient after the application of radiopharmaceuticals, or a car transporting radiopharmaceuticals) - such data should not be published on the measurement map. Information on natural radioactivity values and natural radiometric anomalies can be very useful for data checking. Sharing this (usually already publicly available) information with users can also help prevent public concern if higher gamma dose rates are measured in some locations.

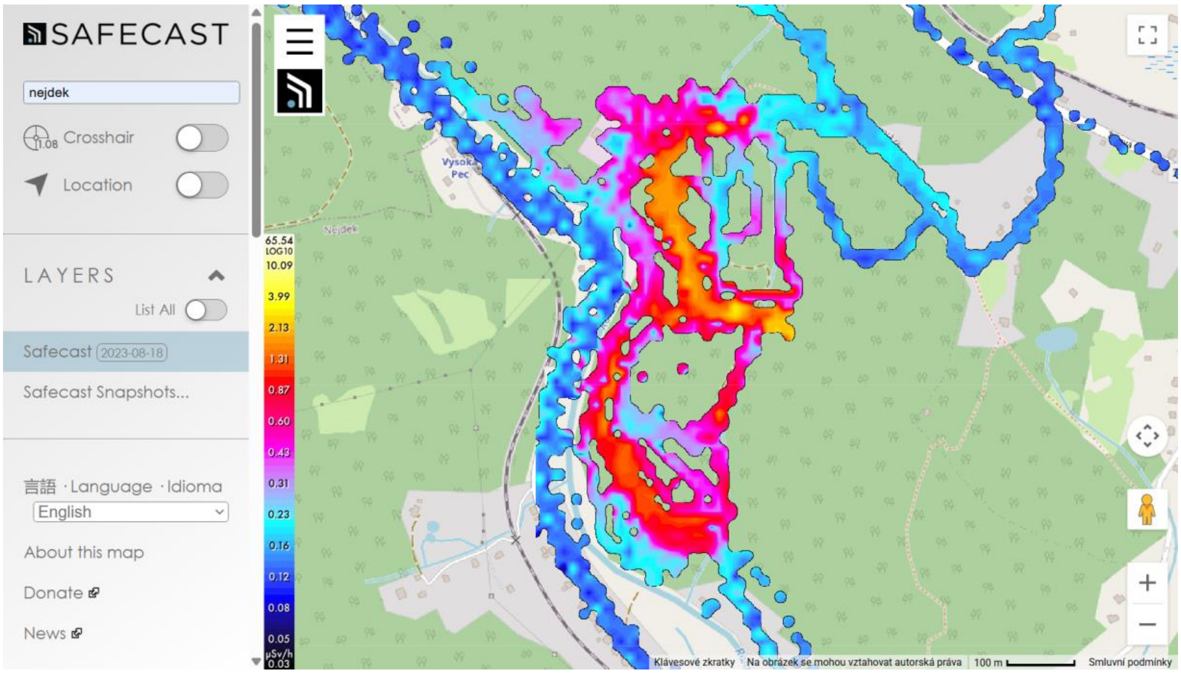

Figure 36. Dose rate mapping results in Nejdek, Czechia (Source: map.safecast.org)

For example, in the Nejdek location, Czech Republic, dose rates of up to 9 µSv/h at 1 meter above the ground were measured in 2015. This is the location of a former uranium ore processing plant, and the location is publicly accessible. Although this information about increased dose rates in the given location is publicly available (similarly to other locations such as Příbram or Jáchymov), there has not yet been any rumours on social media, etc., as some feared. Local residents and "radiation enthusiasts" have known about this for a long time.

SÚRO, on the other hand, provides a public data layer [52] with the location of sites related to radioactive raw materials (exploration, mining, ore processing). Most of this data was previously available in various publicly available sources. Users are of course reminded to measure only in publicly accessible locations.

Figure 37. Example of uranium related places in Příbram region, Czechia (Background map © OpenStreetMap contributors)

Citizen radiation measurements can (in addition to the education mentioned earlier) also be a useful tool for detailed mapping of radiation values (gamma dose rate) on the territory of a given state. In the case of Safecast and CzechRad devices, these are mutually comparable data published under a public license and therefore further usable. In some areas, they may be the only available source of such detailed data. They can therefore represent a useful alternative to existing maps (such as EANR [53], version for QGIS [54]) or national radiometric maps. In addition to its importance for educating citizens (we find places with higher levels of radioactivity in nature), this data can also be used in the event of a radiation event. For example, SÚRO has a so-called Evaluation Center, where the use of citizen measurements in an emergency situation is expected.

4.4 Possibilities to include citizen measurements into the European regulatory framework

European radiation protection is primarily regulated by Council Directive 2013/59/Euratom (Basic Safety Standards, BSS) and its transpositions in EU Member States, as well as international guidelines and standards (IAEA, ICRP, ICRU), which influence EU practice. In principle, this framework does not prohibit measurements by members of the public, but strictly regulates dose assessment and dose limits, official monitoring and reporting obligations, and decision-making related to protective measures. Data from citizen radiation measurements are exempt from these regulations, provided they are marked as supplementary, are not used for dose assessment, and are subject to expert verification and interpretation. European regulators remain cautious about information that could be misinterpreted by the public and trigger unnecessary concern. To mitigate such a situation only verified data should be published with provided explanation and/or risk assessment and best aligned with national radiation protection authorities. **Nevertheless, under normal conditions—that is, outside periods of war or declared emergencies—it is not possible to prevent the publication of locally collected citizen data. Therefore, it is in the interest of local and central governments to proactively engage with organizations or groups conducting citizen measurements by offering expert support, data verification, and cooperative frameworks.**

A critical prerequisite for the scientific usability of citizen measurements is systematic data verification. Verification procedures may include: (i) automated plausibility checks; (ii) spatial and temporal consistency analysis and comparison with nearby official monitoring data where available. **Measurements exhibiting anomalous values should be subject to expert review prior to further use. This type of verification should be performed by competent experts or an expert organization, credible both for authorities and for independent non-governmental organizations.** Only data meeting predefined quality criteria are classified as verified and suitable for integration into situational analyses.

Verified citizen measurement data can be utilized through two parallel pathways. First, data are transmitted in standardized formats to responsible state authorities to support situational awareness, hotspot detection, and prioritization of official measurement resources. Second, verified data are published without delay on publicly accessible web platforms, accompanied by metadata, uncertainty indicators, and explanatory context. This dual dissemination approach balances operational utility with transparency and public trust.

Citizen measurements can substantially improve local-scale radiation information, particularly in areas not covered by fixed monitoring stations. High spatial density of measurements enables detection of localized anomalies and supports fine-scale mapping of radiation fields. Furthermore, structured feedback mechanisms allow experts to guide participants toward additional measurements in areas of interest, thereby refining spatial resolution and reducing uncertainty. The increased measurement frequency and repeated observations at suspected hotspots enable confirmation of elevated radiation levels and assessment of temporal stability. Such adaptive strategies support delineation of affected areas and complement targeted deployment of professional monitoring teams.

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If the measured data are to be publicly available it should be supported by the relevant risk assessment and expert interpretation. Only data published in such a way can enhance public understanding and mitigate misinformation. Citizen measurement data are subject to limitations related to detector performance, calibration variability, environmental influences, and operator behavior. These factors necessitate conservative interpretation and transparent communication of uncertainty. Consequently, citizen-generated data should be explicitly labeled as supplementary and should not serve as the sole basis for regulatory or health protection decisions.

One of the main challenges in using citizen measurement data in the event of a serious nuclear accident or armed conflict is the real possibility of disinformation being exploited by hostile states. This disinformation can be carried out at various levels, ranging from providing significantly inflated or incorrect data to incite panic, to providing data that contradicts official results to demonstrate the system's unreliability. Attempts to incite panic through misinterpretation of measurement results are also to be expected. These considerations can limit the usefulness of the citizen data and enhance the importance of expert data verification.

In summary, the inclusion of the citizen data into the radiation protection framework could be then provided in the following steps:

(i) Recognition of citizen data as supplementary information

Citizen-generated radiation measurements should be formally recognized as supplementary data intended for situational awareness, trend detection, and public engagement. They should not be used directly for regulatory dose assessment or decision-making without expert validation.

(ii) Establishing minimum technical criteria for devices

National authorities should define minimum performance requirements for detector types eligible for data integration. Approved device models should be documented in a public registry.

(iii) Implementation of calibration and cross-validation strategies

Instead of individual calibration of all devices, representative calibration of device models should be conducted at accredited laboratories. Cross-comparison with official monitoring stations and mobile reference measurements should be used to derive correction factors and uncertainty estimates.

(iv) Development of standardized measurement protocols

Authorities, in cooperation with citizen science organizations, should publish simple, standardized measurement and data-reporting protocols, including requirements for metadata (time, location, device type, measurement conditions).

(v) Support of user training and guidance

Basic training resources (online tutorials, manuals, and best-practice guides) should be made available to improve measurement consistency and reduce systematic errors.

(vi) Applying data quality control and expert verification

Automated quality-control methods should be used to identify anomalies and outliers and allow fast throughput of big amounts of data. Aggregated datasets should undergo expert review before dissemination or use alongside official data.

(vii) Ensuring clear labelling and risk communication

All published citizen data should be clearly labelled as non-regulatory, include uncertainty information, and be accompanied by explanatory context to prevent misinterpretation and unnecessary public concern.

(viii) Promotion of institutional cooperation

National authorities should proactively engage with citizen science organizations through formal cooperation agreements, defining responsibilities for data verification, interpretation, and communication.

In conclusion, by integrating verified citizen data within the official information platform of authorities can enhance transparency, improve public trust, and strengthen societal resilience, while maintaining regulatory integrity.

5 Conclusions

Citizen-led radiation measurements have emerged as an important complement to authorized institutional radiation monitoring, particularly following large-scale nuclear or radiological events. This form of participatory monitoring gained significant momentum after the Fukushima Daiichi nuclear accident in 2011. In the aftermath of the accident, a lack of public confidence in official radiation measurements published by the Japanese government and international organizations such as the IAEA motivated citizens to conduct independent measurements using self-developed or low-cost radiation detectors. These initiatives marked a turning point in public engagement with radiation protection and environmental monitoring.

The increasing involvement of citizens in radiation measurements is closely linked to broader societal changes. Modern societies are characterized by higher levels of education, technical competence, and access to affordable technology. As a result, individuals are more capable of understanding basic radiation concepts, operating measurement devices, and providing meaningful data. Citizen science initiatives in radiation monitoring reflect a growing demand for transparency, independent verification, and direct public participation in issues related to health, safety, and the environment.

Within this context, the CITISTRA project represents a concrete effort to evaluate the feasibility of large-scale citizen-based radiation monitoring in Central Europe. The project aims to deploy and test more than 500 radiation detectors across the Czech Republic, Poland, and Slovakia. These devices, produced by the National Radiation Protection Institute, are based on the design principles of Safecast radiometers, which have been widely used in international citizen science networks. CITISTRA seeks to assess not only the technical performance of the detectors but also the organizational, social, and legal conditions necessary for sustaining such a network.

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The motivation for developing and supporting citizen dosimetric measurement systems in Europe extends beyond scientific curiosity or public engagement. Europe hosts a large number of nuclear power plants, and the possibility of major nuclear accidents, although unlikely, cannot be entirely excluded. In addition, the security situation in Europe has deteriorated following the aggression of the Russian Federation against Ukraine, including explicit threats involving nuclear weapons and serious concerns about the safety of nuclear facilities in conflict zones. These developments have heightened public awareness and anxiety regarding radiation risks, further reinforcing the demand for independent and widely distributed monitoring capabilities.

From a legal perspective, the Czech Republic, Poland, and Slovakia have well-established frameworks for radiation protection and emergency response. Although the technical implementation details differ among these countries, their legal systems are harmonized with European legislation, particularly the Euratom Basic Safety Standards. These frameworks define responsibilities, monitoring requirements, emergency preparedness measures, and decision-making processes in the event of nuclear or radiological incidents.

However, under the current legal conditions in all three countries, data generated by citizen radiation measurements cannot be directly used for regulatory purposes. Regulatory decisions, such as dose assessment, protective actions, or enforcement measures, must be based on measurements performed by accredited institutions using certified equipment and validated methodologies. This restriction reflects the need to ensure data reliability, traceability, and legal accountability in radiation protection.

Nevertheless, citizen-generated radiation data have clear potential value and should not be dismissed. Such measurements can provide supplementary information that enhances situational awareness, supports early trend detection, and contributes to public engagement and risk communication. Citizen data may help identify unusual radiation patterns, prompt further investigation by authorities, and increase public trust through transparency and shared responsibility. Importantly, these data should be clearly distinguished from official regulatory measurements and should only be used after appropriate expert review and validation.

To responsibly integrate citizen radiation measurements into the broader radiation protection framework, several steps are necessary. First, minimum technical criteria for citizen measurement devices should be established, including requirements for sensitivity, stability, and energy response. Second, calibration and cross-validation strategies must be implemented, for example through comparison with reference instruments or periodic checks at designated calibration laboratories. Third, standardized measurement protocols should be developed to ensure consistency in measurement conditions, data recording, and reporting. Finally, verification of the data must be performed by an expert organisation.

Education and training are equally critical. Citizens participating in radiation measurements require guidance on proper detector use, interpretation of results, and limitations of the data. Online tutorials, manuals, and workshops can play an important role in building competence and reducing systematic errors. In addition, robust data quality control mechanisms and expert verification procedures should be applied before citizen data are shared or interpreted in a broader context. Clear labelling of data quality, uncertainty, and intended use is essential to prevent misinterpretation or unnecessary public concern.

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Institutional cooperation is another key element. Effective citizen monitoring networks require collaboration between national authorities, research institutions, non-governmental organizations, and citizen groups. Such cooperation can help align expectations, share expertise, and ensure that citizen initiatives complement rather than conflict with official monitoring systems.

A critical challenge facing citizen radiation measurement initiatives is long-term sustainability. Continuous funding is required to support detector maintenance and servicing, data infrastructure, software updates, and ongoing education of participants. Without stable financial support, citizen networks risk gradual degradation, loss of data quality, and declining public engagement. To address this issue, the establishment of national competence centers is recommended. These centers would be responsible for verifying citizen measurements, providing technical support, coordinating training activities, and ensuring continuity of the monitoring networks.

In conclusion, citizen radiation measurements raise important social and legal questions but also offer significant opportunities. When properly supported, regulated, and integrated, they can enhance radiation monitoring, strengthen public trust, and improve preparedness for radiological emergencies. Projects such as CITISTRA demonstrate that citizen science can play a constructive role in radiation protection, provided that its limitations are acknowledged and its contributions are embedded within a robust legal and institutional framework.

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7 References

[1] IAEA Power Reactor Information System (PRIS)
https://pris.iaea.org/PRIS/

[2] Jaderná elektrárna Temelín
https://cs.wikipedia.org/wiki/Jadern%C3%A1_elektr%C3%A1rna_Temel%C3%ADn

[3] Jaderná elektrárna Mochovce
https://cs.wikipedia.org/wiki/Jadern%C3%A1_elektr%C3%A1rna_Mochovce

[4] Six SMR power plants approved in Poland; World Nuclear News (WNN); Friday, 8 December 2023
https://www.world-nuclear-news.org/Articles/Six-SMR-power-plants-approved-in-Poland

[5] ORLEN Group focuses on affordable, safe and clean energy; press release; 7 April 2023
https://www.orlen.pl/en/about-the-company/media/press-releases/2023/april-2023/ORLEN-Group-focuses-on-affordable-safe-and-clean-energy

[6] Monitoring rádioaktivity životného prostredia
https://www.shmu.sk/sk/?page=20

[7] Radiation Monitoring https://www.gov.pl/web/paa-en/radiation-monitoring2

[8] EUropean Radiological Data Exchange Platform - Joint Research Centre Data Catalogue
https://data.jrc.ec.europa.eu/collection/id-00136

[9] Facts and figures on the European Union
https://european-union.europa.eu/principles-countries-history/facts-and-figures-european-union_en#header_countries_list

[10] QGIS Distance matrix
https://docs.qgis.org/3.40/en/docs/user_manual/processing_algs/qgis/vectoranalysis.html#distance-matrix

[11] 10 let od havárie jaderného reaktoru v Černobylu - důsledky a poučení (in English: 10 years since the Chernobyl nuclear reactor accident - consequences and lessons learned) State Office for Nuclear Safety / National Radiation Protection Institute report, Prague, 1996
https://sujb.gov.cz/fileadmin/sujb/docs/dokumenty/10let_od_Cernobylu.pdf

[12] 35 let od havárie v Černobylu (SÚJB) (in English: 35 years since the Chernobyl accident; State Office for Nuclear Safety)
https://sujb.gov.cz/fileadmin/sujb/docs/cernobyl/2021/Havarie_Cernobyl_-_35_let_pote.pdf

[13] Deposition from Chernobyl in Europe [online]. Copenhagen: European Environmental Agency, 2021 [cit. 2021-04-19]. Available from: https://www.eea.europa.eu/data-and-maps/figures/deposition-from-chernobyl-in-europe

[14] Bučina, I., Kunz, E., Malátová, I., & Drábová, D. *Monitoring of post-Chernobyl contamination in the Czech Republic (pp. p. 1045–1048)*; Proceedings of the first international conference 'The radiological consequences of the Chernobyl accident'; , Minsk (Belarus), 18-22 Mar 1996, ISSN: 1018-5593
https://inis.iaea.org/records/fnes2-ymj55

[15] Archiv Rudého Práva - Ústav pro českou literaturu AV ČR. v.v.i
http://archiv.ucl.cas.cz

[16] Vaněk, M.; Černobyl – krize věrohodnosti. Politické dopady černobylské tragédie; State Office for Nuclear Safety (SÚJB)
https://sujb.gov.cz/fileadmin/sujb/docs/cernobyl/Cernobyl_krize_verohodnosti.pdf

[17] Škrkal, J., Rulík, P., Fantínová, K., Mihalík, J., Timková, J. *Radiocaesium levels in game in the Czech Republic.* Journal of Environmental Radioactivity 2015, 139: 18-23,
doi: 10.1016/j.jenvrad.2014.09.016

[18] Survey: Czechs are the most pro-nuclear nation in Europe, Feb 12, 2025
https://www.euractiv.com/section/politics/news/survey-czechs-are-the-most-pro-nuclear-nation-in-europe/

[19] Standard Eurobarometer 102 - Autumn 2024, published: November 2024
https://europa.eu/eurobarometer/surveys/detail/3215

[20] European Commission, Directorate-General for Communication, 'Special Eurobarometer SP557 : European citizens' knowledge and attitudes towards science and technology', version v1.00, 2025, accessed 2025-04-14,
http://data.europa.eu/88u/dataset/s3227_102_1_sp557_eng

[21] IBRS: Podpora jaderné energie v České republice je na vzestupu (29. 7. 2025)
https://www.protext.cz/english/press-release/ibrs--podpora-jaderne-energie-v-ceske-republice-je-na-vzestupu/19194

[22] Naskalski, J.W., et al Przegląd Lekarski 2004 /61 / 12 *Analityczne aspekty badania niedoboru jodu w trakcie realizacji Programu Badania Niedoboru Jodu w Polsce*

[23] Krajewski, P. *Ocena równoważników dawek obciążających w tarczycy dla ludności Polski w wyniku wchłonięć 131I po awarii w Czarnobylu. Określenie efektu blokady tarczycy jodkiem potasu.* Endokrynol Pol 1991; 42: 189–202

[24] Szybiński, Z. et al *Incidence of thyroid cancer in the selected areas of iodine deficiency in Poland* J Endocrinol Invest, 2003;26(2 Suppl):63-70.

[25] Pierwsze doniesienia o katastrofie czarnobylskiej, jako komunikat PAP, pojawiły się 29 IV 1986 r. w gazetach południowych oraz serwisach radiowych i telewizyjnych. http://przystanekhistoria.pl/pa2/tematy/propaganda/99138,Pierwsze-doniesienia-o-katastrofie-czarnobylskiej-jako-komunikat-PAP-pojawily-si.html

[26] Report on a WHO Workshop Helsinki, Finland 17–19 September 2000 WORKSHOP ON STABLE IODINE PROPHYLAXIS AFTER NUCLEAR ACCIDENTS EUR/01/5020969

[27] Jaworowski, Z (2010) Formerly Nonlinearity in Biology, Toxicology, and Medicine, Dose-Response, 8:148–171, 2010 ISSN: 1559-3258, DOI: 10.2203/dose-response.09-029.Jaworowsk

[28] Pietrzak-Flis, Z., Krajewski, P., Radwan, I., Muramatsu Y. R*etrospective evaluation of 131I deposition density and thyroid dose in Poland after the Chernobyl accident.* Health Physics 2003, 84: 698–708

[29] Zonenberg, A., Zarzycki W., Leoniak M. *The effect of Chernobyl accident on the development of malignant diseases - situation after 20 years.* Endokrynologia Polska Vol. 57; Number 3/2006

[30] 2011 Tōhoku earthquake and tsunami
https://en.wikipedia.org/wiki/2011_T%C5%8Dhoku_earthquake_and_tsunami

[31] Fukushima nuclear accident
https://en.wikipedia.org/wiki/Fukushima_nuclear_accident

[32] Státní úřad pro jadernou bezpečnost - Havárie na jaderné elektrárně Fukušima I - 10 let poté (English: State Nuclear Safety Authority - Fukushima I Nuclear Power Plant Accident - 10 Years Later)
https://sujb.gov.cz/fileadmin/sujb/docs/Fukusima/2021/Havarie_na_jaderne_elektrarne_Fukusima_I_-_10_let_pote.pdf

[33] Radiation monitoring in Japan (Wikipedia)
https://en.wikipedia.org/wiki/Radiation_monitoring_in_Japan

[34] Japan Radiation Map Roundup, 25 Mar 2011, by Lauren Schenkman
https://www.science.org/content/article/japan-radiation-map-roundup

[35] Xively (Wikipedia)
https://en.wikipedia.org/wiki/Xively

[36] History of Safecast
https://safecast.org/history-of-safecast/

[37] RDTN.org: Radiation Detection Hardware Network in Japan
https://www.kickstarter.com/projects/1038658656/rdtnorg-radiation-detection-hardware-network-in-ja/posts

Co-funded by the European Union

[38] Announcing “bGeigies for Ukraine”, 20 July 2022, by Azby Brown
https://safecast.org/announcing-bgeigies-for-ukraine/

[39] Over 300,000 data points gathered by #bgeigies4ukraine!, 17 September 2022, by Azby Brown, https://safecast.org/over-300000-data-points-gathered-by-bgeigies4ukraine/

[40] PRESS RELEASE: Safecast/SaveDnipro joint independent realtime radiation monitoring system now operational in Ukraine, 5 August 2024
https://safecast.org/press-release-safecastsavednipro-joint-independent-realtime-radiation-monitoring-system-now-operational-in-ukraine/

[41] Radioactive@Home, http://radioactiveathome.org/en/

[42] Thread 'New Project - Radioactive@Home'
https://boinc.n-helix.com/forum_thread.php?id=6686

[42] Nové projekty, https://forum.czechnationalteam.cz/viewtopic.php?t=1987&start=40

[43] Radiation Monitoring Network for institutions and schools to assure early awareness and enhancing safety of citizens (RAMESIS)(VI20152019028)
https://starfos.tacr.cz/en/projekty/VI20152019028

[44] Center for the support of the population in case of actual or suspected occurrence of extraordinary nuclear and radiation events (VJ01010116)
https://starfos.tacr.cz/en/projekty/VJ01010116

[45] State Office for Nuclear Safety - National Radiation Emergency Plan (NRHP)
https://sujb.gov.cz/fileadmin/sujb/docs/dokumenty/NRHP/NHRP_ENG.pdf

[46] State Office for Nuclear Safety - National Monitoring Programme
https://sujb.gov.cz/fileadmin/sujb/docs/radiacni-ochrana/NMP/NMP_text_en.pdf

[47] The Safecast Report, Volume 1. March 2015
http://safecast.org/downloads/safecastreport2015.pdf

[48] Coletti, M., Hultquist, C., Kennedy, W.G., Cervone, G. *Validating Safecast data by comparisons to a U. S. Department of Energy Fukushima Prefecture aerial survey.* J Environ Rad. 2017, 171: 9-20, doi: 10.1016/j.jenvrad.2017.01.005.

[49] IAEA FINAL REPORT (2013 to 2022) Radiation Monitoring and Remediation Following the Fukushima Daiichi Nuclear Power Plant Accident Cooperation between Fukushima Prefecture and the IAEA

[50] Kuča, P., Helebrant, J., Bossew. P. *Citizen monitoring of ambient dose rate: the SAFECAST project.* Radiation Protection Dosimetry 2023, 199(8-9):775-780, doi: 10.1093/rpd/ncad079

[51] Morosh, V. , Röttger, A., Neumaier, S., Krasniqi, F., Živanović, M., Kržanović, N., Pantelić, G., Iurlaro, G., Mariotti, F., Sperandio, L., Bell, S., Ioannidis, S., Kelly, M., Sangiorgi, M.. *Investigation into the performance of dose rate measurement instruments used in non-governmental networks.* Radiation Measurements 2021, 143: 106580, doi: 10.1016/j.radmeas.2021.106580

[52] Open dataset of uranium mines and deposits
https://github.com/juhele/opengeodata/tree/master/Open_geodataset_of_uranium_mines_and_deposits

[53] European Atlas of Natural Radiation
https://remon.jrc.ec.europa.eu/About/Atlas-of-Natural-Radiation

[54] European Atlas of Natural Radiation datasets for QGIS etc.
https://github.com/juhele/opengeodata/tree/master/EANR_data

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