MINISTRY OF SOCIAL AFFAIRS AND HEALTH

National action plan for identifying existing exposure situations (KAVATTU)

PUBLICATIONS OF THE MINISTRY OF SOCIAL AFFAIRS AND HEALTH 2023:28

Reports and Memorandums of the Ministry of Social Affairs and Health 2023:28

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Ministry of Social Affairs and Health Helsinki 2023

Julkaisujen jakelu
Distribution av publikationer

Valtioneuvoston julkaisuarkisto Valto

Publikations-
arkivet Valto

julkaisut.valtioneuvosto.fi

Ministry of Social Affairs and Health

ISBN pdf: 978-952-00-9869-8
ISSN pdf: 1797-9854

Layout: Government Administration Department, Publications

Helsinki 2023 Finland

Description sheet
29 September 2023

National action plan for identifying existing exposure situations (KAVATTU)

Publications of the Ministry of Social Affairs and Health 2023:28

Publisher	Ministry of Social Affairs and Health

Author(s)	Kurttio, Päivi; Kallio, Antti; Turtiainen, Tuukka; Leikoski, Niina; Virtanen, Sinikka; Mattila, Aleksi; Keski-Jaskari, Pia; Markkanen, Mika; Tanhua-Tyrkkö, Merja; Aallos-Ståhl, Siiri-Maria; Hellstén, Santtu;		
Group author	Radiation and Nuclear Safety Authority in Finland		
Language	English	**Pages**	38

Abstract

Article 100 of the Directive laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation 2013/59/Euratom requires Member States to identify existing exposure situations. In this regard, Article 100 has been implemented in Finland in section 142 of the Radiation Act. This national action plan sets out procedures and proposes respon-sible parties to identify the above-mentioned situations. When an existing exposure situation has been identified, it is managed in accordance with the procedures laid down in chapter 17 (Existing exposure situations) of the Radiation Act.

Keywords radiation, radiation by source, Radiation and Nuclear Safety Authority, The Ministry of Social Affairs and Health, existing exposure situation, Radiation Act

ISBN PDF	978-952-00-9869-8	**ISSN PDF**	1797-9854
Reference number		**Project number**	VN/3439/2021
URN address	https://urn.fi/URN:ISBN:978-952-00-9869-8		

Kuvailulehti
29.9.2023

Kansallinen toimintasuunnitelma vallitsevien altistustilanteiden tunnistamiseksi (KAVATTU)

Sosiaali- ja terveysministeriön julkaisuja 2023:28

Julkaisija	Sosiaali- ja terveysministeriö

Tekijä/t	Kurttio, Päivi; Kallio, Antti; Turtiainen, Tuukka; Leikoski, Niina; Virtanen, Sinikka; Mattila, Aleksi; Keski-Jaskari, Pia; Markkanen, Mika; Tanhua-Tyrkkö, Merja; Aallos-Ståhl, Siiri-Maria; Hellstén, Santtu;		
Yhteisötekijä	Säteilyturvakeskus STUK		
Kieli	Englanti	**Sivumäärä**	38

Tiivistelmä

Säteilyturvallisuusdirektiivin 2013/59/Euratom artiklassa 100 vaaditaan jäsenmaita tunnistamaan vallitsevia altistustilanteita. Tältä osin artikla 100 on Suomessa toimeenpantu säteilylain 142 §:ssä. Tässä kansallisessa toimintasuunnitelmassa esitetään menettelyjä ja ehdotetaan vastuutahoja edellä mainittujen tilanteiden tunnistamiseksi. Kun vallitseva altistustilanne on tunnistettu, sitä hallinnoidaan säteilylain 17 luvussa (Vallitsevat altistustilanteet) säädetyin menettelyin.

Asiasanat	säteily, säteily lähteen mukaan, Säteilyturvakeskus, sosiaali- ja terveysministeriö, vallitseva altistustilanne, säteilylaki		
ISBN PDF	978-952-00-9869-8	**ISSN PDF**	1797-9854
Asianumero		**Hankenumero**	VN/3439/2021
Julkaisun osoite	https://urn.fi/URN:ISBN:978-952-00-9869-8		

Presentationsblad
29.9.2023

Nationell handlingsplan för identifiering av befintliga exponeringssituationer (KAVATTU)

Social- och hälsovårdsministeriets publikationer 2023:28

Utgivare	Social- och hälsovårdsministeriet		
Författare	Kurttio, Päivi; Kallio, Antti; Turtiainen, Tuukka; Leikoski, Niina; Virtanen, Sinikka; Mattila, Aleksi; Keski-Jaskari, Pia; Markkanen, Mika; Tanhua-Tyrkkö, Merja; Aallos-Ståhl, Siiri-Maria; Hellstén, Santtu;		
Utarbetad av	Säteilyturvakeskus		
Språk	Engelska	**Sidantal**	38

Referat

Artikel 100 i strålskyddsdirektivet 2013/59/Euratom kräver att medlemsländerna identifierar befintliga exponeringssituationer. Denna del av artikel 100 har genomförts i Finland genom 142 § i strålsäkerhetslagen. Denna nationella handlingsplan presenterar förfaranden och föreslår ansvariga för identifiering av de ovannämnda situationerna. När en befintlig expneringssituation har identifierats hanteras den i enlighet med de förfaranden som föreskrivs i 17 kap. i strålsäkerhetslagen (Befintliga exponeringssituationer).

Nyckelord strålning, strålning enligt källa, Strålsäkerhetscentralen, social- och hälsovårdsministeriet, befintlig exponeringssituation, strålsäkerhetslag

ISBN PDF	978-952-00-9869-8	**ISSN PDF**	1797-9854
Ärendenummer		**Projektnummer**	VN/3439/2021
URN-adress	https://urn.fi/URN:ISBN:978-952-00-9869-8		

Contents

1 Background

In accordance with section 142 of the Radiation Act (859/2018), the Ministry of Social Affairs and Health draws up a national action plan for identifying existing exposure situations and for the implementation of the measures referred to in the plan. On the basis of the definitions in the Radiation Act, an *existing exposure situation* means an exposure situation attributable to ionizing radiation which does not constitute an emergency exposure situation or radiation practice. The Radiation Act identifies two types of the existing exposure situations, which are divided into chapters 17 and 18 of the Radiation Act (Table 1). This action plan addresses the exposure situations referred to in chapter 17 of the Radiation Act, in which the responsible party cannot be easily identified, so the identification of the situations and the consideration of measures requires special planning. A practice causing exposure to natural radiation in accordance with chapter 18 of the Radiation Act, on the other hand, refers to ongoing or planned practices for which there is typically a clear party responsible for the practice, who must carry out the investigations required by law and take the necessary measures to limit exposure to natural radiation. In addition, the practice is subject to a safety licence if the occupational or public exposure arising from the activity or the radon concentration in workplace or household water exceeds the reference level despite the measures taken.

Table 1. The division of existing exposure situations in the Radiation Act. This national action plan drawn up on the basis of section 142 of the Radiation Act discusses situations referred to in chapter 17 of the Radiation Act to identify existing exposure situations.

Existing exposure situations referred to in chapter 17 of the Radiation Act (Government Decree on Ionizing Radiation 1034/2018, section 49), which are discussed in this action plan	Existing exposure situations (practices with exposure to natural radiation) pursuant to chapter 18 of the Radiation Act, which are not covered by this action plan
1) past activities that were never subject to regulatory control or were not regulated in accordance with the requirements at the time of drawing up the plan 2) emergency exposure situations from which a transition was made to an existing exposure situation 3) practices for which the undertaking responsible cannot be identified 4) naturally occurring radioactive substances in situations other than those provided for in chapter 18 of the Radiation Act 5) radioactive substances in products intended for consumer use from the situations referred to in points 1–4, with the exception of food, animal feed, household water and construction products	a) radon in indoor air (workplaces, other premises used by people, dwellings, construction projects) b) manufacture, import or transfer of construction products[1] (external gamma radiation from construction products) c) production of household water (plants providing water for household use) d) aviation e) other practices with exposure to natural radiation (the processing, use, storage and utilisation of soil, rock or other materials occurring in nature or materials resulting from the use of these materials, such as mining, preparation of ore and metal processing)

Article 100 of the Directive laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation 2013/59/Euratom requires Member States to identify existing exposure situations. In this regard, Article 100 has been implemented in Finland in section 142 of the Radiation Act. The explanation for section 142 of the Radiation Act states that the national action plan shall include measures to identify the existing exposure situations specified in Annex XVII to the Directive 2013/59/Euratom. Points 1) to 3), 5), a) and b) are listed in said Annex XVII for the exposure situations listed in Table 1 above. Of these, point a), radon in indoor air, is included in a separate National Radon Action Plan already drawn up on the basis of section 159 of the Radiation Act for the prevention of long-term risks arising from radon (Ministry of Social Affairs and Health 2020). Due to this, the matters covered by chapter 18 of the Radiation Act are excluded from this action plan even though some of them are included in Annex XVII to Directive 2013/59/Euratom.

1 With regard to point b), the present action plan only deals with the period before 1991 (covered by point 1 of Table 1), since radiation exposure from construction products was already regulated under the previous Radiation Act (592/1991) and is still regulated under the current Radiation Act.

This national action plan **sets out procedures and proposes responsible parties to identify the above-mentioned situations**. Measures to identify existing exposure situations may include drive-based separate investigations of certain types of special sites, such as old extractive waste sites or landfills, or the creation of mechanisms in connection with other monitoring, such as national environmental radiation monitoring and regulatory control of radiation practices. When an existing exposure situation has been identified, it is managed in accordance with the procedures laid down in chapter 17 (Existing exposure situations) of the Radiation Act.

2 Existing exposure situations that may lead to radiation exposure

2.1 Discontinued practices that were not subject to regulatory control or were not regulated like similar practices

Discontinued practices include the use of radioactive substances before the Radiation Protection Act (174/1957) entered into force. Other examples include waste areas (mining waste areas) containing naturally occurring radioactive substances from mines that closed before the entry into force of the previous Radiation Act (592/1991) on 1 January 1992 or old landfill sites containing waste from practices causing exposure to natural radiation.

2.1.1 Procedures and parties responsible for identifying situations

Discontinued practices with exposure to natural radiation are already known to the Radiation and Nuclear Safety Authority (STUK) because the sites have been previously examined or monitored to investigate the exposure situation or to determine the carry-over of naturally occurring radioactive substances. In addition, STUK has participated in procedures related to the closure, post-mining management or remediation of some sites, so information on the sites is already available.

Closed and abandoned mining waste areas in Finland have been systematically surveyed in KAJAK projects[2] (Räisänen et al. 2013; Tornivaara et al. 2018). The survey was carried out by the Finnish Environment Institute, the Geological Survey of Finland (GTK) and the Centres for Economic Development, Transport and the Environment (ELY Centres) of Kainuu and North Ostrobothnia on behalf of the Ministry of the Environment. The surveying of mining waste areas is based on the EU Directive on the management of waste from extractive industries 2006/21/EC, according to which closed or abandoned mining waste areas causing serious environmental contamination or potential threat to the environment must be inventoried. The inventory, which was last updated on 9 January 2020, includes 31 mining areas with 42 mining waste areas. Only a few of these

2 KAJAK project website: https://maaperakuntoon.fi/fi-FI/Ohjelmat_ja_hankkeet/KAJAK

sites are known to contain naturally occurring radioactive substances in concentrations higher than the average concentration in bedrock, but precise concentration data are not available for all sites. In the order of priority approved by the Ministry of the Environment, the KAJAK follow-up projects examine the status of mining waste areas, assess the need for remediation and continue to remediate the areas with a risk-based approach depending on the site, either at the expense of the party responsible for the practice or at the expense of the state (Tornivaara et al. 2020). STUK's role in relation to KAJAK projects is to act as a radiation expert in cooperation between authorities in locations where the concentrations of naturally occurring radioactive substances are significant, as necessary. In the future, the information obtained from KAJAK projects can be utilised when assessing whether measures are needed due to exposure to natural radiation. The follow-up studies and rehabilitation of KAJAK sites are coordinated by the ELY Centre of Pirkanmaa, and the work will continue well into the future.

In addition to abandoned mining waste areas, STUK is also aware of **pending mining projects at the planning or licensing stage, the area of which is known to contain materials with naturally occurring radioactive substances originating from the previous operator's discontinued operations**. These areas of pending mining projects are not included in the above-mentioned KAJAK inventory. New mines to be opened are supervised as practices with exposure to natural radiation in accordance with chapter 18 of the Radiation Act. The new mining operator must also take care of the existing mining waste located in the mining area and its disposal, insofar as it is disturbed by the new mining operations or if the new mining operations could have an impact on the long-term persistence of the existing waste. If the mining project does not lead to mining operations, it may be necessary to take into account existing mining waste containing naturally occurring radioactive substances in other further use of the land if the land use becomes such that exposure could occur.

Information on the radioactive substances of an old waste area is best preserved for future generations and can be taken into account in the land use of the area if the information is included in the area's plan notations, the building information system and the environmental administration's databases on contaminated land. Finland has imposed one prohibition on measures concerning real estate due to radioactive substances pursuant to the Nuclear Energy Act (section 63, subsection 1, paragraph 6) in the former uranium mining area of Paukkajanvaara (STUK document number Y102/40). Similar prohibitions cannot be imposed on the basis of the Radiation Act. Today, when radioactive waste or waste resulting from practices with exposure to natural radiation is disposed of in active landfills, future land use is already considered to be subject to certain restrictions due to the existence of the landfill approved by the environmental authorities. It is not likely that, after the closure of the landfill, the land use of a landfill area subject to an environmental permit and noted in the land use plan would be changed in such a way that the waste deposited in the landfill would be detrimental to the new intended purpose. Closed landfills are not priority areas for housing for example but are used for example as recreational areas or for other purposes where exposure is low. The quantities of naturally occurring radioactive substances that have ended up in very old landfills, either unintentionally or intentionally, are not fully known.

An example of radiation-related plan notations is the Rauhalahti ash mound area in Jyväskylä, where peat ash was piled after the Chornobyl[3] accident in the late 1980s (STUK 2019). The plan for the area in question includes a notation that if excavation work is to be carried out in the area, an opinion on the matter must be requested from STUK. The ash mound was covered some time ago, and there has been a recreational area on top of it for a long time, so the exposure caused by land use is low. Several opinions related to the area have been issued by STUK over the past 30 years concerning, for example, the laying of underground cables, the installation of fitness equipment and other excavation work. The activity concentration of caesium-137 and, consequently, the risk of radiation exposure is constantly decreasing as a result of the radioactive decay of caesium. By and large, old ash mounds are not significant sources of exposure because, at the current activity concentrations, old sites meet the condition concerning the use of ash in earthworks (Regulation STUK S/6/2022, section 13). If the ash is kept covered, the risk of exposure arising from ash mounds can be found to be low.

2.1.2 Identified sites

Closed mines and mining waste areas in the KAJAK inventory

The Korsnäs lead mine (active from 1961 to 1972) produced not only lead concentrate but also 36,000 tonnes of enriched apatite containing lanthanides. The lead refining generated 760,000 tonnes of tailings, which were was deposited in a tailings area. The enriched lanthanide was piled near the quarry to wait for sale but, after the mining operations ended, the mound was left in the mining area. The enriched lanthanide and the tailings area contain naturally occurring radioactive substances in higher concentrations than are normally present in soil. The post-mining management of the mining area has been monitored by STUK (Radiation and Nuclear Safety Authority 1992; 1998b). In the enriched lanthanide, the activity concentration of uranium-238 is approximately 2,000–4,000 Bq/kg, the activity concentration of radium-226 is 2,000–8,000 Bq/kg and the

3 This document uses the Ukrainian transliteration of the name of the Chornobyl accident site (formerly known as Chernobyl from the Russian) in accordance with the SFS 4900 standard.

activity concentration of thorium-232 is 1,000–2,000 Bq/kg (Radiation and Nuclear Safety Authority 1992; Suominen 2020). In the tailings, the activity concentration of uranium-238 is approximately 600–900 Bq/kg, the activity concentration of radium-226 is 500–900 Bq/kg and the activity concentration of thorium-232 is 200–400 Bq/kg (Radiation and Nuclear Safety Authority 1992; Suominen 2020). Based on a thesis commissioned by STUK on the current state of radioactivity in the Korsnäs lead mine (Suominen 2020), exposure to natural radiation is known to be low with current land use. However, the municipality has plans to increase the recreational and other use of the area. Korsnäs is a KAJAK monitoring site in 2022 and 2023[4]. The monitoring also includes more precise measurements of radiation and radioactive substances. The follow-up report will be completed at the end of 2023, and an opinion will be requested from STUK.

The Vihanti mine was in operation from 1954 to 1992. The ore in Vihanti contained zinc, copper, lead and silver (Tornivaara et al. 2018). The uranium deposit in Lampinsaari in Vihanti was discovered during systematical examination of drill core deposits in the 1970s. In the early days of the mine, the uranium-rich part was probably mined along with other rock, and its remnants may be found in the waste area. STUK supervised the post-closure management measures of the waste area (Mustonen 2007). Based on the thesis commissioned by STUK on the current state of radioactivity of the closed mine in Vihanti (Suominen 2020), the exposure to natural radiation is known to be low with current land use. Approximately 14,000 tonnes of tailings were deposited in the waste area of the Vihanti mine (Tornivaara et al. 2018), including approximately 300 Bq/kg of uranium series radionuclides and approximately 10 Bq/kg of thorium series radionuclides (Suominen 2020).

Pending mining projects, the areas of which also contain old waste (not included in the KAJAK inventory)

Juomasuo in Kuusamo has a gold-cobalt deposit, where copper, tungsten, uranium and molybdenum are also found (Mustonen 2007). The deposit underwent small-scale exploratory extraction and enrichment in the early 1990s (Anttonen 1993) and has been under the control of several different companies since then. On average, the uranium concentrations in the Juomasuo and Hangaslampi deposits are approximately 150–300 mg/kg (the activity concentration of uranium-238 is approximately 2,000–4,000 Bq/kg), but the concentrations in individual samples containing uranium nitrate may be higher than 1,000 mg/kg (Kuusamo gold mine project's EIA report 2013). The gold-cobalt project currently underway in Juomasuo is still in the exploration survey phase.

4 KAJAK project page for Korsnäs: https://maaperakuntoon.fi/fi-FI/Ohjelmat_ja_hankkeet/KAJAK/Korsnas

The area of the ongoing Hannukainen mining project includes the old tailings area of Rautuvaara (1962–1995), which contains a total of 9,500 tonnes of tailings from the enrichment of several different ores (Rautuvaara, Kuervaara, Laurinoja, Saattopora, Pahtavuoma), including approximately 17,000 tonnes of tailings from gold ore from Juomasuo in Kuusamo (Räisänen et al. 2015). The tailings from Juomasuo are found as a thin layer among other tailings. Their uranium content is approximately 470 mg/kg (Räisänen et al. 2015), which corresponds to the activity concentration of uranium-238 of 5,800 Bq/kg. Similar uranium concentrations are known to occur in the gold ores from Juomasuo and Hangaslampi in Kuusamo (Kuusamo gold mine project's EIA report 2013). A thesis on the current state of radioactivity in Rautuvaara was commissioned by STUK (Pelkonen 2018). Since the thesis was published, the tailings area has been covered and post-closure management measures have been conducted (Decisions 85/2014/1 and 94/2019 of the Regional State Administrative Agency for Northern Finland). The area may be used again in the pending Hannukainen mining project. The exposure to natural radiation caused by the covered tailings in Rautuvaara is low.

The phosphate and niobium ores found in the Sokli area in Savukoski contain uranium and thorium in higher concentrations than the average in the soil and bedrock in Finland. In phosphate ore, the activity concentration of uranium-238 is on average 300 Bq/kg and the activity concentration of is thorium-232 is 500 Bq/kg. In niobium ore, the activity concentration of uranium-238 is on average 1,000 Bq/kg and the activity concentration of thorium-232 is 4,000 Bq/kg (Solatie et al. 2010). The Sokli deposit was discovered in 1967, and the area underwent phosphate exploratory extraction and enrichment in the 1980s, as well as exploration surveys for several decades. The activity levels of naturally occurring radioactive substances in the environment of the Sokli deposit, such as the water, sediments and plants, are not higher than the average in Finland (Solatie et al. 2010). A phosphate mining project is still under discussion in Sokli. Its environmental permit was returned to the Regional State Administrative Agency for preparation in 2022 by a decision of the Supreme Administrative Court. The uranium and thorium concentration must be taken into account, as in all new mining projects, if the mine minerals in the area are to be utilised.

Old sites related to exploratory extraction of uranium

From 1958 to 1961, approximately 31,000 tonnes of ore were mined from the old uranium mine of Paukkajanvaara in the municipality of Eno with an average uranium concentration of approximately 0.12% (Sillanpää et al. 1989; Mustonen et al. 1989). The waste was disposed of on the basis of the Nuclear Energy Act, and the area was found to have been acceptably remediated in 2001 (STUK document number Y102/39). Any monitoring will be carried out in accordance with the Nuclear Energy Act, and there is a prohibition on land use in the area.

The Askola experimental enrichment plant was built for the study of the Lakeakallio uranium deposit. Lakeakallio had a mining claim with a small experimental quarry from 1957 to 1958. The enrichment plant building was dismantled and the open pit mine and the tailings area of the experimental enrichment plant were covered in the 1980s (Mustonen 2007). There are also other small pits in the vicinity from which samples were taken. In addition, a batch of ore from the deposit on Käldö island in Pernaja was brought to Lakeakallio. Käldö island also has exploratory extraction pits and a pile of weakly radiating rock waste.

Experimental enrichment was carried out at a mobile enrichment plant in the Nuottijärvi area in Paltamo in 1965. There is still a small pile of partially radiating rock waste at the site. In 1968, ore was extracted from the deposit and delivered to Pori for experimental enrichment (Mustonen 2007).

Completed operations from the time of the previous Radiation Act 592/1991 that had STUK's approval at the time

Old ash mounds from the early 1990s can be found, for example, in Jyväskylä (STUK, 2019) and Noormarkku. The radiation exposure caused by old covered ash mounds is low if no significant changes occur in land use.

In Kokkola's Ykspihlaja industrial area, radium from the raw material for the production of cobalt salts and its decomposition products ended up in the plant area's tailings pool as iron residue. Approximately 30,000 tonnes of iron residue was piled over an hectare of land between 1996 and 1998. The activity concentration of radium-226 in the waste pile was approximately 20,000 Bq/kg (Radiation and Nuclear Safety Authority 1998a). This waste represents only a very small part of the industrial area's large hazardous waste landfill, which is still in use. Other iron residue waste in the landfill contains smaller amounts of naturally occurring radioactive substances and covers the radium-containing waste.

Crushed engine parts of Draken fighter aircrafts were deposited at the Riikinneva hazardous waste landfill (1.5 tonnes, thorium content approximately 4% by weight) in a trench together with metal-contaminated soil in 2005, with approval in accordance with the Nuclear Energy Act (Radiation and Nuclear Safety Authority 2005).

In Outokumpu, process waste from pyrochlorine ore enrichment experiments was disposed of in the mining waste area of the mineral processing experiment site (approximately 2,000 tonnes, concentrations of uranium and thorium series nuclides approximately 10,000 Bq/kg; Radiation and Nuclear Safety Authority 2007). Experimental activities in mineral technology are still under way, and the land use of the mining waste areas is not expected to change.

2.1.3 Recommendations for action

STUK participates in the planning of the monitoring of old mining waste areas through KAJAK projects in cooperation with other authorities. If necessary, information on naturally occurring radioactive substances will be included in the reporting of KAJAK monitoring sites. The affected municipalities are involved in the planning of site monitoring and remediation, so the municipalities receive the necessary information through the KAJAK projects.

Information on naturally occurring radioactive substances should be added to the land use plan and the environmental administration's databases as needed so that they can be taken into account in any future changes in land use.

If the ongoing mining projects in Sokli, Hannukainen or Juomasuo do not lead to mining operations in the future and the areas end up being used for other purposes, STUK will assess whether measures are needed in these areas due to exposure to natural radiation.

In accordance with its resources, STUK will carry out or commission separate studies on the current status of closed operations in, for example, Askola and Paukkajanvaara (as has been done previously in the cases of the mining waste areas of Rautuvaara, Korsnäs and Vihanti).

STUK will assess whether it is necessary to carry out monitoring of old landfills and ash mounds and, if necessary, plan a separate project for environmental radiation monitoring or another research project to carry out measurements in these areas.

2.2 Emergency exposure situations from which a transition was made to an existing exposure situation

Such situations include, for example, non-acute cleaning operations following an emergency exposure situation, which may take a long time. If the emergency exposure situation results in long-term effects on the living environment, the post-situation phase will be followed by a recovery phase. At this point, the radiation situation in the living environment will be permanently acceptable in terms of society, and the activities of people and society will be adjusted to the existing radiation situation (Radiation and Nuclear Safety Authority 2020). According to section 137 of the Radiation Act, the government decides on the transition from an emergency exposure situation to an existing exposure situation once the measures necessary to limit the radiation hazard and bring the radiation sources under control have been carried out. In existing exposure situations, protective actions are to be carried out in such a way that occupational and public exposure remain below the reference level set. Reference levels are set with consideration to the principles of radiation protection and acceptability in terms of society.

In an existing exposure situation, the reference level of public exposure, as an effective dose, may be at maximum 10 millisieverts per year (mSv/year) (Decree of the Ministry of Social Affairs and Health on ionizing radiation 1044/2018, section 17). The reference level may be set at less than 1 mSv/year if it relates to a specific area or other object or to a specific exposure pathway associated with a specific area or other object. STUK confirms the reference levels for members of the public in an existing exposure situation (Radiation Act, section 140).

In an existing exposure situation, the reference level of occupational exposure in protective actions, as an effective dose, is 1 mSv/year (Decree of the Ministry of Social Affairs and Health 1044/2018, section 16). If the occupational exposure exceeds the reference level, a safety licence must be applied for (Radiation Act, section 141).

The most significant emergency exposure situation affecting Finland's environment has been the 1986 accident at the Chornobyl nuclear power plant, which caused a widespread radioactive fallout throughout Europe. The fallout that spread to Finland was surveyed in 1987 (Arvela et al. 1990), and municipalities were divided into fallout zones 1–5. In 1987, the area with the highest fallout, zone 5, had a caesium-137 fallout of 45–78 kBq/m2, which, due to the radioactive half-life of caesium, now corresponds to a surface activity contamination of about 23–35 kBq/m2. Radioactive substances were also released into the environment by global fallout after nuclear weapons testing in the 1950s and 1960s. The accident at the Fukushima Daiichi Nuclear Power Station in 2011 caused a negligible increase in the annual radiation dose to the Finnish population.

2.2.1 Procedures and parties responsible for identifying situations

STUK is responsible for environmental radiation monitoring in Finland, annually monitoring the activity concentrations of artificial radioactive substances in air samples, fallout, surface and household water, milk, food and sewage sludge. In addition, the monitoring programme includes separate thematic studies. The programme has been designed to detect changes in radioactivity in the environment, react to changes, assess human radiation doses, and plan and advise measures to reduce doses. The radiation monitoring programme maintains expertise and readiness to react quickly and correctly to abnormal radiation situations. Separate studies can be used to find out more detail about possible important sources of radiation exposure.

An example of a separate project for environmental radiation monitoring is a project carried out in 2021–2022 to examine the activity concentrations of radioactive substances in the ashes of Finnish waste incineration plants (Kallio et al. 2023). Waste incineration plants from different parts of Finland contributed to the project. Some plants only used municipal waste as fuel, while others also used other types of waste. Energy recovery of waste has been the most important form of municipal waste treatment since 2012. In 2020, it accounted for 58% or more than 1,900,000 tonnes of waste (Official Statistics of Finland 2020). No activity concentrations of artificial or naturally occurring radionuclides that would have restricted reuse were found in the examined ash batches.

Internal radiation exposure to humans can be estimated by direct gamma spectrometric measurement, also known as whole-body counting. Whole-body counting can be used to detect and quantify radionuclides emitting gamma or X-ray radiation in the body at the time of measurement. The most significant artificial radioactive substance in terms of accumulation of the dose caused by internal radiation is caesium-137. In Finland, whole-body counting has been used since the 1960s to monitor the amount of radioactivity in humans. The highest levels of caesium-137 activity found in humans were measured in the mid-1960s in northern Lapland reindeer herders, whose lifestyle involved the ingestion of large amounts of natural products and reindeer meat. Following the accident at the Chornobyl Nuclear Power Plant, new monitoring groups for whole-body counting were set up. In the area with the highest fallout, Päijät-Häme, a monitoring group of people who consume a lot of natural products, such as hunters and fishermen, was established.

Currently, the average external radiation dose caused by fallout from the Chornobyl accident and nuclear weapons tests is approximately 0.01 mSv/year (Siiskonen 2020). Most of the external and internal radiation exposure is caused by caesium-137. Artificial radionuclides in food cause an effective dose of approximately 0.003 mSv/year internally, so the total dose of artificial radionuclides is approximately 0.01 mSv. These doses are well below the minimum reference level of 0.1 mSv/year for existing exposure situations. In the current situation, there is no need for additional measures in terms of average exposure; STUK's national environmental radiation monitoring programme is sufficient. If new emergency exposure situations arise in Finland or in the neighbouring regions in the future, the monitoring programme will be updated as necessary.

2.2.2 Identified sites

After an accident at a nuclear power plant or another emergency exposure situation, the transition to an existing exposure situation can be made once the necessary measures to limit the radiation hazard and bring the radiation sources under control have been carried out. In Finland, varying amounts of radioactive materials are still detected in the environment as a result of the Chornobyl accident and nuclear weapons testing in the 1950s and 1960s.

2.2.3 Recommendations for action

STUK will continue its national environmental radiation monitoring programme. The content of the programme will be evaluated with a risk-based approach, taking into account regulatory obligations and the development of measurement techniques and sampling methods.

Information on the occurrence of radioactivity in subjects outside the scope of regular monitoring will be obtained by means of separate studies.

2.3 Practices where the undertaking responsible cannot be identified

Situations in which the undertaking responsible cannot be identified may involve the discovery of an orphan source[5] or, in the worst case, environmental contamination caused by a damaged orphan source when its handling is not part of practices subject to a safety licence referred to in section 86 of the Radiation Act.

The discovered orphan source might be a sealed source, in which case the radioactive material has remained sealed in a container or case. However, the container or case might also break, releasing radioactive material into the environment, in which case it is an open source. In the latter case, the finder of the source may be faced with extensive decontamination work to remove the radioactive material and to demonstrate that the contaminated area is clean.

5 Orphan source means a radioactive source which is not in the possession of the undertaking entitled to its use or possession.

2.3.1 Procedures and parties responsible for identifying situations

In Finland, the use of radiation sources and their care after decommissioning has been monitored since the 1960s, and radiation sources have been individually recorded in STUK's electronic register since the 1980s. The monitoring has been effective in preventing radiation sources in Finland from ending up as orphan sources. A few orphan sources are found in Finland every year. The finder of an orphan source is usually someone who had nothing to do with the radiation source.

Section 86 of the Radiation Act states that practices that repeatedly handle or store orphan sources are subject to a safety licence. A safety licence is required from large operators, for which the detection and handling of radiating objects is considered a recurring, continuous activity and not just a sporadic radiation safety deviation. Three such safety licences have been issued in Finland. Two of the safety licences were issued to metal recycling companies and one to a steelworks importing scrap metal. These operators had identified the risk of finding orphan sources and invested in more expensive and accurate radiation measurement systems (such as a radiation portal monitor to detect radioactive material in a vehicle at the scrap yard gate/entrance). More accurate measurement systems help to detect even small radioactivity concentrations indicative of orphan sources, preventing radioactive substances from ending up in recycled metal. Since more accurate measurement systems have helped to find orphan sources, this has led to the operator having to apply for a safety licence for the handling of orphan sources.

Some smaller operators in the metal recycling industry (such as scrap yards) have access to simpler radiation measurement instruments (in practice, dose rate and surface contamination meters), which enable the detection of the most active radiation sources. However, it is not known to STUK how many companies in the industry have a radiation meter at their disposal. There are a few hundred smaller operators in the metal recycling industry in Finland.

An undertaking that suspects or knows about an orphan source must notify STUK in accordance with section 86 of the Radiation Act. However, this does not apply to undertakings that do not have a safety licence (as they are not undertakings as defined in or referred to by the act). Over the years, however, many smaller operators have notified STUK of their finds, but there is no certainty that STUK has been notified of all finds.

When an undertaking finds an orphan source that is in a sealed container or case, the undertaking typically delivers the source to Suomen Nukliditekniikka Oy (or STUK in the case of nuclear materials) and pays the costs of disposal.

When an operator without a safety licence finds an orphan source, it is recommended that the operator first contact STUK. STUK will then determine what measures it will take. If the radiation source has not appeared to be damaged and the costs of decommissioning have not been unreasonably high, the operator has delivered the radiation source to Suomen

Nukliditekniikka Oy and has often borne the costs itself. However, if there has been a suspicion that the radiation shielding of the source has been damaged or the operator has not had the know-how or measuring equipment to measure radioactive substances, STUK's experts may have visited the site to take more exact measurements. In the event of an emergency, the operator must, in accordance with the Rescue Act, contact the Emergency Response Centre.

In Finland, there are also operators with mobile measuring equipment, equipment maintenance activities and expertise (such as radiation safety experts) that can reliably determine the radionuclides, activity and possible environmental contamination of the orphan sources found. These operators also offer their measurement expertise to others as a paid service.

More detailed measurements are carried out to assess the magnitude of radiation exposure of workers and the orphan source's radionuclide and its radioactivity. The identification of the nuclide and assessment of radioactivity are essential, among other things, because they affect the disposal costs of the radiation source and the possible transport arrangements of hazardous materials.

If the undertaking with the duty of care for the discovered radiation source has not been found within a reasonable time, the radiation source has been taken over by the state on the basis of the state's secondary duty of care (Radiation Act, section 80).

In the case of an open source or if the radiation source been melted and radioactive material has ended up in the slag or in indoor air as dust formed in the melting process, the undertaking must commence cleaning operations to clean the premises and equipment and bear the costs.

When a small operator notifies STUK of having found an orphan source, it expects rapid advice and measurement assistance from STUK. It takes STUK's personnel from a few days to weeks to investigate the situation. STUK has not had a separate project to deal with these situations, so the costs have been covered by STUK's operating budget. This has been done to prevent the finder of an orphan source from incurring a penalty-like charge for the work done by the authorities and the disposal of the radiation source. If the finder had to cover all the costs, it might lead to future finds not being reported.

The Radiation Act does not take a stand on what is a large or small operator. Section 86 of the Radiation Act provides only that practices which repeatedly handle orphan sources are subject to a safety licence. Operators that invest in the purchase of more accurate radiation measurement systems also find orphan sources repeatedly.

For the smallest operators, acquiring costly measurement systems and the associated measurement expertise and maintenance may result in disproportionately high costs in relation to the size of the operation. In addition, for a smaller operator, the competence requirements and costs related to the processing of orphan sources, carrying out radiation measurements, packaging, transport, disposal and cleaning the environment and the associated costs may result in the operator not reporting any orphan sources found.

Problems with the cost of handling orphan sources have also been observed in other countries. For example, the following practices have been established in EU countries in order to reduce the costs incurred by the state in situations where one or more orphan sources are found.

- The largest metal recycling companies are required to provide a guarantee of at least EUR 110,000, which can be used if the company finds an orphan source but is close to bankruptcy and is therefore unable to cover the costs of the orphan source.
- If the owner of an orphan source cannot be found, the finder may apply for assistance from the state for the costs arising from the proper disposal of the radiation source. The decision is influenced, for example, by how diligently the finder has tried to discover the original owner of the radiation source, and the state will not cover all the costs in all situations.
- A few countries have set up a special fund to cover the costs of properly disposing of orphan sources.
- In some countries, the finder of an orphan source always pays the costs of its proper disposal.
- In other countries, all the costs associated with an orphan source are borne by the radiation safety authority/state from a fund set up for this purpose. Ten per cent of the annual regulatory control fees collected by the radiation safety authority are transferred directly to the fund, which can be used to cover the costs incurred from orphan sources.

2.3.2 Identified sites

An orphan source can be found, for example, in Customs border control among other goods, in a metal recycling company or in a steelworks importing metal scrap. Orphan sources can also be found in properties where someone other than the current owner of the premises used them long ago. In a few cases, a radiation source has also been found in the estate of a deceased person. In addition, consumers and collectors may be in possession of old clocks or other consumer products in which radioactive substances were once used. STUK receives questions related to the handling of such consumer products approximately once a month. The legislation relating to such old products is not unambiguous.

Table 2 presents the situations reported to STUK in which radioactive material has entered the melting process of a steelworks. According to the undertaking, the clean-up costs incurred by the company for one melting are more than EUR 100,000.

Table 2. Situations reported to STUK between 2012 and 2021 where radioactive material entered the metal melting process of a steelworks.

Year	Number of accidental meltings
2012	1
2013	1
2014	2
2015	1
2016	0
2017	1
2018	3
2019	1
2020	5
2021	2
Total	17

Table 3 presents the reports entered in STUK's register of found orphan sources. Only in one case had the shielding of the radiation source broken such as to force the metal recycling company that reported the radiation source to take cleaning measures. In such a situation, the radioactive waste generated by the clean-up must be handled appropriately, and smaller operators may not have the expertise. It should be noted that there is no operator in Finland that has the safety licence required by the Radiation Act to handle open source waste. Operators who handle open sources, solidify any open source waste they may have themselves. After solidification, the open source waste has been handed over to an operator that handles radioactive waste. These open source operators may offer the solidification of open source waste as a service to other operators.

Table 3. Numbers of found orphan sources entered in STUK's register between 2012 and 2021. The sources have been taken care of by the owner, the finder or STUK.

Year	Numbers of orphan sources reported to STUK	Owner not found	Number of sources taken over by the state as STUK's secondary duty of care
2012	1	1	-
2013	8*	4	
2014	8*	7	
2015	8*	7	1
2016	4	2	1
2017	15	15	
2018	6	4	
2019	1	1	1
2020	13**	12**	3
2021	60**	26**	25**
Total	124	79	31

* Several sources were found at a single operator's site at the same time, but the exact number is no longer known.

** The sources were provided by a private person (such as a collector). The high number in 2021 is due to the fact that two private individuals gave up their collectibles (34 + 22 in total) during the year.

2.3.3 Recommendations for action

The problem of orphan sources is also known internationally, and the IAEA Code of Conduct on the Safety and Security of Radioactive Sources (IAEA 2004) states that every State should have a national strategy for orphan sources and that every State should provide for rapid response for the purpose of regaining control over orphan sources. Finland has undertaken to comply with the Code of Conduct by the Ministry of Social Affairs and Health's letter 170/04/2003 sent on 15 April 2004.

In relation to this, a strategy should be drawn up under the leadership of the Ministry of Social Affairs and Health on how to handle orphan sources in Finland in the future. A wide range of stakeholders (such as the Rescue Department and radiation safety experts) should be involved in the preparation of the strategy. Clarification of the matter may also require a review of the legislation. The lack of a national strategy was noted in the previous review by the Integrated Regulatory Review Service (IRRS) in 2012, but the strategy has not yet been developed.

2.4 Naturally occurring radioactive substances in situations other than those provided for in chapter 18 of the Radiation Act

The situation referred to here may be related to, for example, an area where the soil or bedrock holds naturally occurring radioactive substances in amounts that cause significantly higher exposure to people in the area than normal background radiation.

Practices with exposure to natural radiation, which are separately regulated in chapter 18 of the Radiation Act, are already separately subject to comprehensive notification and investigation obligations, so they have been excluded from this action plan (Table 1).

2.4.1 Procedures and parties responsible for identifying situations

In Finland, STUK measures dose rates using an external radiation monitoring network with approximately 260 measuring stations (Mattila & Inkinen 2020). The level of background radiation in Finland typically varies between 0.05 and 0.30 microsieverts per hour (µSv/h). Local variation in dose rates mainly results from differences in the content of uranium in the bedrock and soil. Variations in thorium and potassium concentrations account for less of the dose rate variation. At typical uranium and thorium concentrations, external gamma radiation from the bedrock and soil is mainly caused by bismuth-214 and lead-214, which are short-lived radon-222 decay products in the radium-226 decay series. However, bedrock and soil rock have an activity balance between uranium-238 and radium-226, so the amount of external radiation correlates not only with radium-226 but also with the uranium content of the bedrock and soil.

Finland's bedrock is known to have several small uranium deposits, the excavation of which has not been economically viable. Uranium exploration has been carried out at various times and Finland's uranium deposits have been described in many different studies (e.g. Lauri et al. 2010, Lauri 2012, Äikäs 2000, 2007, Pohjolainen 2015). The Geological Survey of Finland studied the presence of uranium in Lapland in 2019, at which time areas stood out in radiometric data (Eerola & Nousiainen 2019). STUK's URAKKA report (Mustonen et al. 2007) also listed the areas with the most significant uranium potential.

The results of geophysical aerial surveys can be used to try to find areas with abnormal radiation levels by using aeroradiometric measurements to determine the gamma radiation variation in the Earth's crust. Aeroradiometric maps made by the Geological Survey of Finland can be found in its public online services[6], which provide background information for the identification of areas with abnormal radiation. However, aeroradiometric maps are generally not unambiguous to interpret. Observed radiation is affected by factors like soil cover (such as vegetation), soil composition and water content. Not all known uranium deposits are exposed on the Earth's surface, so they do not generate direct radiation observations.

If areas with radiation levels clearly higher than normal background radiation were identified and the area were associated with an obvious exposure risk, STUK would investigate the resulting radiation exposure and, if necessary, set a reference level for radiation exposure. At the moment, STUK is not aware of any such areas in Finland. People occasionally spending time outdoors will not receive significant radiation exposure from short periods of time near, for example, uranium mineralisation; significant exposure would require a longer time (for example, living or continuously working in the vicinity). Reference levels in a situation under chapter 17 of the Radiation Act are set on a case-by-case basis between 0.1 and 10 mSv/year, taking into account both radiation protection criteria and acceptability in terms of society (Radiation Act, section 140, Decree of the Ministry of Social Affairs and Health, 1044/2018, section 17). Since typical background radiation can computationally cause a dose of 0.8 mSv/year (maximum typical background radiation 0.3 μSv/h; 1,600 h/year of outdoor work and 1,000 h/year of other activities outdoors; Jones et al. 2019), the reference level for natural bedrock and soil cannot be considered to be under 1 mSv/year. A more precise reference level between 1 and 10 mSv/year would be set taking into account the specific characteristics of the area, the exposure risks, the size of the population and the costs to society of the possible measures compared to the benefits to be achieved. The reference level cannot be more than 10 mSv/year, so the most important thing in identifying exposure situations is to first determine whether there are areas where public exposure could exceed that limit. This is not likely, so the identification of exposure situations must, in practice, examine whether there are areas in Finland where exposure to radiation from the bedrock and soil is likely to exceed 1 mSv/year for a large population. Such areas are not expected to be found, as major population centres are not located near known mineralisations. The uranium mineralisations in Finland are small and also occur in connection with other ores. It is not likely that new residential areas would be established near known ore deposits. However, it is not entirely impossible that, in the long term, the expansion of residential areas could

6 Public online services with aeroradiometric include https://hakku.gtk.fi/en, https://gtkdata.gtk.fi/mdae/index.html

encounter sites with higher background radiation levels. If necessary, the matter can be examined with geospatial surveys of the development of residential areas compared to the locations of known uranium or thorium mineralisations.

2.4.2 Identified sites

Waste from the removal of radioactive substances from household well water

Approximately 60,000 households in Finland use water from bored wells. Naturally occurring radioactive substances, especially radon and uranium, may be present in excessive concentrations in well water. Many of these households and holiday homes use filters, such as activated carbon or ion exchange resin, to remove the radioactive substances. The used filtering masses contain radioactive substances.

Construction products and earthworks materials from before 1991

Radioactivity in construction products has been regulated and controlled since the Radiation Act of 1991 (592/1991). The act stipulated that the gamma radiation emitted by construction materials must not expose the population to more than 1 mSv per year compared with the unbuilt environment. There was no regulation of the radioactivity of building materials used in buildings built before the entry into force of the act, and regulation has not been extended to them retroactively. Based on the radioactivity measurements conducted by STUK, it is known that radiation exposure exceeding the reference level (1 mSv/year) set down in current legislation can occur mainly in residential buildings with concrete structures built using granite rock as a concrete aggregate. This mean that it is possible that, before the entry into force of the Radiation Act of 1991, concrete residential buildings were built that emit radioactivity causing a radiation exposure of over 1 mSv/year to their residents. As far as is known, radium-containing blue concrete (blåbetong), the use of which in residential construction had caused higher radiation exposure (radon and gamma radiation) to residents in Sweden, has never been used as a building material in mainland Finland. However, citizens have voiced suspicions that blue concrete has been used on the Åland islands. Because the monitoring of the radioactivity of construction products is based on independent investigations by the producers of the materials, the population exposure reference level of 1 mSv/year may be exceeded in concrete residential buildings if the producer has neglected its investigation obligation.

Of the substances contained in construction products that produce external gamma radiation (uranium and thorium series radionuclides and potassium-40), only radium-226 of the uranium series produces radon. Because of this, it is difficult to find blocks of flats with excessive amounts of naturally occurring radioactive substances in concrete structures on the basis of radon measurements. The ventilation efficiency stipulated in the Building Code of 1989 (0.5 h–1) has probably been ensured during the general overhaul of many old blocks of flats. Effective ventilation keeps the radon concentration below the reference level even if the radium-226 concentration in construction products has increased.

The reference level of a construction product used in residential construction is defined as the increase in the effective dose caused to the population by the gamma radiation of construction products compared with the unbuilt environment. After construction, any buildings exceeding the reference level cannot be easily found through measurements. For example, an additional effective dose of 1,000 µSv (1 mSv) per year corresponds to a dose rate of only 0.14 µSv/h in housing (7,000 hours/year). This is difficult to distinguish from the background radiation in Finland, which normally varies between 0.05 and 0.30 µSv/h.

Burnt alum shale (incompletely burned, crushed and screened shale that may contain a small amount of oil) is widely used in Finnish sports fields. The amount of naturally occurring radioactive substances in the gravel is above average, so the dose rate levels in such sports fields may be higher than in the rest of the environment. Burnt alum shale is considered as a building material and is regulated as a construction product in accordance with chapter 18 of the Radiation Act. Sports fields with burnt alum shale preceding the entry into force of the Radiation Act of 1991 could be considered as falling under chapter 17 of the Radiation Act. The interpretation is complicated by the fact that the burnt alum shale fields still in use are maintained by adding more gravel from time to time. Therefore, the building material of the fields that are still in use can be considered to be subject to construction product control regardless of when the field was originally built.

Thoron (radon-220)

Radon is defined in the Radiation Act as the radon-222 isotope (Radiation Act, section 4) and exposure to it is comprehensively regulated (Radiation Act, chapter 18). Radon also has a short-lived isotope radon-220, or thoron, which is not subject to the regulation provided for in chapter 18. As such, it is one of the situations referred to in section 142 of the Radiation Act and discussed in this action plan.

Thoron belongs to the thorium series and is released by all thorium-containing minerals. Thoron has a half-life of only 56 seconds, so it quickly disappears from the air. Due to its short half-life, its concentration is very unevenly distributed. However, as it decays, thoron produces lead-212, a moderately long-lived decay product. Lead-212 has a half-life of 10.6 hours and accounts for the majority of the radiation dose from thoron exposure.

Extensive thoron measurements in homes, public buildings and workplaces in the Netherlands found that previous studies had incorrectly measured thoron as radon, so the estimates of radon and thoron exposure were updated (Smetsers et al. 2018, Goemans et al. 2018). This means that thoron and its decay products can be found in homes, workplaces and recreational areas in Finland as well. However, it is unlikely that the effective doses caused by thoron or its decay products would exceed 1 mSv/year. Thoron and its decay products were studied in some underground workplaces in Finland in the 1970s and 1990s, and these measurements did not find any concentrations causing significant exposure (Markkanen, oral communication, 2023). Significant exposure to thoron can only be assumed to occur in poorly ventilated rooms where large quantities of thorium-containing minerals are handled or stored, or in rooms built from construction products containing significant amounts of thorium-series elements (such as radium-228). Measuring the activity concentration of thoron and its decay products requires special measuring instruments. STUK has measuring instruments that can traceably measure thoron concentrations and others that can observe thoron decay products in the air.

Circular economy

As the circular economy grows, the aim is to recycle and utilise, for example, the side streams and waste fractions generated by industry as efficiently as possible. The possibilities of utilising old mining waste have also been examined (Vesa 2021). Mining waste may contain recoverable materials because they could not be separated with the original methods used, their recovery was not considered important at the time or they were not even identified. However, some mining waste, side streams and waste fractions may contain above-average quantities of naturally occurring radioactive substances. The reuse of mining waste must also take into account naturally occurring radioactive substances in the material. If the radioactivity of recycled raw materials is not taken into account in product and material development, the exposure to natural radiation caused by the product or material may exceed the reference level.

Uranium deposits

Finland is known to have several small uranium deposits, the excavation of which has not been economically viable. Known deposits where the main mining mineral is uranium or thorium can be found in the deposit database of the Geological Survey of Finland[7]. Uranium is found in many ore deposits with, for example, gold, copper or molybdenum (Lauri et al. 2010). Below are the most notable areas of uranium deposits in Finland.

7 Deposit database of the Geological Survey of Finland https://gtkdata.gtk.fi/mdae/index.html

- Kaltimo in Koli has several small uranium deposits that belong to Koli National Park and the closed mining area of Paukkajanvaara. The average concentration of known uranium deposits in the area between Koli and Eno varies from 0.08% to 0.14%.
- Uusimaa stands out radiometrically and geochemically as an area with a higher concentration of uranium in the bedrock and groundwater in large areas than the rest of Finland. Nummi-Pusula has the Palmottu deposit, which contains 0.1% uranium.
- In Kolari-Kittilä (Kesänkitunturi, Aakenustunturi and Pahtavuoma), the Kesänkitunturi deposit has an average uranium concentration of 0.06%.
- Kuusamo (Kouervaara) has several small uranium deposits and uranium minerals in connection with gold deposits.

Other known uranium deposits that have also been described are Lakeakallio in Askola, Nuottijärvi in Paltamo, Lampinsaari in Vihanti, Korsnäs and other, smaller deposits include Temo in Nilsiä, Kisko, Sokli in Savukoski, Juomasuo in Kuusamo and Vuolijoki. In 2008, AREVA discovered uranium and gold ore in the Rompas-Rumavuoma area. At the moment, inventory-phase gold and cobalt exploration is being carried out in the area, and an environmental impact assessment has been initiated for the preparation of a programme (Vasara 2021). In a study of the uranium deposits in Lapland using radiometric data, areas that stood out were Sokli, Pomokaira and Nattaset, the Sevettijärvi and Suolisjärvi area and the northern part of Enontekiö (Eerola and Nousiainen 2019).

Many areas with uranium deposits have undergone some form of exploratory extraction and are no longer in a completely natural state. STUK has no reason to suspect that the exposure caused by the uranium deposits would exceed the reference level for the population unless there are changes in land use (Mustonen et al. 2007).

2.4.3 Recommendations for action

Potential radiation hazards should be taken into account when new recycled materials are introduced or when the reuse of old mining waste starts as the circular economy grows. Design and product development should take into account that industrial side streams or waste fractions may contain above-average quantities of naturally occurring radioactive substances. When possible radioactive substances in materials are taken into account already at the design and product development stage, the finished products and materials will not expose the population to radiation exceeding the reference level. Future circular economy projects should, as far as possible, increase the information available on potential radiation hazards, for example through STUK's opinions and guides.

The transfer of information, for example in the case of mining waste or other waste materials containing naturally occurring radioactive substances, should be ensured even though it is not mentioned in radiation legislation. If possible, the information could be included in an already existing register or in plan notations for materials whose naturally occurring radioactive substances should be taken into account in the further use of the area or material. Under the leadership of the Ministry of Social Affairs and Health, it should be investigated whether existing registers, such as the Matti database or plan notations, could also be utilised in the transfer of information on naturally occurring radioactive substances.

The coverage of radioactivity measurements of construction products can be determined in cooperation with the construction product control of the Finnish Safety and Chemicals Agency Tukes. In its control of construction products that are subject to the requirement to declare the radioactivity of the product, Tukes may determine whether the radioactivity has actually been measured and whether the information on radioactivity has been reported in the Declaration of Performance (DoP) and the CE marking. If Tukes finds deficiencies in this, it will notify STUK of the deficiencies for further measures.

Many households and holiday homes using water from bored wells use filters, such as activated carbon or ion exchange resin, to filter out the radioactive substances. The used filtering masses contain radioactive substances. Chapter 18 of the Radiation Act does not take a stand on such household waste, and guidelines are needed for its safe disposal, both for households and for the ELY Centres and municipalities that supervise waste treatment. STUK's earlier guide on the waste generated in household water treatment[8] must be updated in the future.

The possible use of blue concrete on the Åland Islands could be investigated by examining aerial survey data of gamma radiation from the Åland Islands or by interviewing local renovation construction operators. However, small buildings made of blue concrete may not be detectable from aerial survey data. Sports fields with burnt alum shale containing above-average quantities of naturally occurring radioactive substances can also be detected by aerial surveys or by using the Geological Survey of Finland's airborne radiometric survey data.

Situations where thoron exposure is most likely to occur should be surveyed by measurements. It is reasonable to start the work with a risk-based approach with the workplaces reported to STUK's regulatory control of natural radiation as workplaces that handle and store materials containing above-average amounts of thorium. Based

8 Guide: Talousveden radioaktiivisten aineiden poistosta syntyvien jätteiden käsittely (Management of waste generated by the removal of radioactive substances from household water) https://urn.fi/URN:NBN:fi-fe2014120250174

on the measurement results presented in the literature, measurements can potentially be extended to sites where the thoron exposure is caused by something other than the processing or storage of minerals. It makes sense to leverage the work by drawing up a measurement protocol for thoron exposure for the workplaces where thoron exposure must be determined as part of exposure to natural radiation (selection of measurement points, duration of measurements, whether thoron gas or decay products will be measured, calculation of a dose estimate based on the measurement result, etc.).

Based on current knowledge, deposits in the natural state with above-average concentrations of uranium or thorium do not require action. Since they are not located in densely populated areas, they are unlikely to lead to exposure above the reference levels for large populations. The number of population centres in the mineralisation areas should be studied in more detail by means of geospatial surveys, for example as thesis research. Dose rate measurements at selected sites could be included in the thesis.

Radiation legislation requires that the exposure caused by natural radiation be investigated in mining practices. By developing cooperation between authorities, it is possible to share information on the requirements of radiation legislation for those responsible for the practice at an early stage before the practice is started. The exchange of information between STUK and the mining and environmental authorities on future mining projects must be maintained.

2.5 Radioactive substances that have ended up in consumer products

The consumer products referred to here include consumables that have been inadvertently contaminated as a result of one of the situations referred to in points 1) to 4) above. In accordance with the provisions of the Directive 2013/59/Euratom, food, animal feed, construction products and household water have been excluded from the products.[9] This plan does not examine consumer products to which radioactive substances have been intentionally added, even if the original purpose of the addition is not related to radiation.[10]

9 Provisions concerning the deliberate mixing of radioactive substances with consumer goods are laid down in sections 68 and 69 of the Radiation Act and in chapter 18 of the Radiation Act concerning construction products and household water.

10 These include camera lenses containing thorium in which thorium is used to influence the refractive index of the lens, and uranium glassware, in which uranium is added to colour the glass.

2.5.1 Procedures and parties responsible for identifying situations

Customs carries out radiation measurements at Finland's borders, and STUK's field measurement unit provides remote and expert support for radiation measurements. Observations are usually made with radiation portal monitors. Alarms are also set off by natural radioactive substances, which are reported to STUK's regulatory control of natural radiation. The cooperation between Customs and STUK provides information on transboundary movement of radioactive materials.

If necessary, STUK investigates the radioactivity concentrations of consumer products based on risk assessments.

In separate projects, STUK can investigate, for example, the radioactivity of bark mulch, wood pellets or ash from household wood combustion. Bark mulch is made from the outer layer of wood bark, which is known to accumulate more caesium-137 than stemwood (Vetikko et al. 2015). Domestic wood ash may have elevated levels of caesium-137 activity if the wood originates from the zones with the highest Chornobyl fallout. Ash from the combustion of wood pellets imported from Eastern Europe is also suspected to have elevated of caesium-137 activity concentrations. STUK has conducted small-scale studies on the radioactivity of ash from wood pellet combustion, but a thorough investigation of the matter would require further studies. Based on the results, it would be possible to draw up a guide for consumers in case the radioactivity of the ash should be taken into account in the reuse of the ash in households.

The radioactivity of timber was last investigated in Finland in the period 2013–2014 (Vetikko et al. 2015). The quantity of naturally occurring radioactive substances in timber is insignificant from the point of view of radiation doses. The concentrations of caesium-137 are also low, with the highest measured activity concentration being 97 Bq/kg. This figure could be used to calculate that the effective dose due to caesium-137 in a house built entirely of logs is less than 0.03 mSv/year. It is therefore clear that consumer products made of wood do not cause significant additional radiation exposure to consumers, either.

However, there is always more caesium in the bark than in the timber, with the highest measured concentration in pine bark being 766 Bq/kg. The ash content of pine bark is about 2%, so the caesium-137 activity concentration of the ash from the combustion of the pine bark in question would be about 40 000 Bq/kg. If fuels made from wood bark from the top fallout zone are sold to households, the resulting ash may cause radiation exposure if it is stored close to living quarters (for example, in a barrel on the other side of the wall of the bedroom) instead of being appropriately disposed of. However, the area with the highest fallout is relatively small nationally (Arvela et al. 1990), so it can only produce a limited amount of fuel made from bark. Fuel production uses material from trees of different ages and mixes materials from different parcels of land, so the production of large quantities of wood-based fuel with a high concentration of caesium is highly unlikely. The activity concentration of caesium-137 in timber is at its highest about 15 to 25 years after the fallout, after which the radioactive half-life of caesium-137 mainly controls its slow removal from timber (Goor & Thiry 2004). Consequently, the activity concentration of caesium-137 in timber is not expected to increase further in Finland.

2.5.2 Identified sites

Customs has observed natural radiation deviating from the level of normal background radiation in, for example, timber, potassium in the fertiliser industry, raw materials for refractory products and grinding balls containing ceramic zirconium.

Consumers may end up with wood bark pellets which, when combusted, produce ash with a significant caesium-137 activity concentration.

Citizens may have in storage consumer products containing radioactive substances.

2.5.3 Recommendations for action

STUK will maintain information on consumer products in which radioactivity may occur on its website[11] In the same context, it is necessary to provide guidance on how those consumer products can be disposed of as waste.

STUK will maintain the cooperation with Customs to ensure that transboundary products containing radioactive materials are detected as efficiently as possible.

Monitoring of caesium-137 levels in Finnish timber from the area with the highest Chornobyl fallout, and in particular in bark products intended for combustion, may be necessary over the next 10 to 20 years until a reduction in the concentrations in felled trees has been demonstrated by sample measurements.

11 https://stuk.fi/en/radioactivity-in-consumer-products.

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ISSN 1797-9854 (PDF)
ISBN 978-952-00-9869-8 (PDF)