Radioprotection, vol. **44**, n° 5 (2009) 607–612

DOI: 10.1051/radiopro/20095112

Half a century of radioecological research and surveillance at STUK

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Abstract. STUK was established in spring 1958 with the main policy to keep research and regulatory activities under the same roof. Radioecological research focused first on environmental surveillance and effects of nuclear weapon tests in the environment and agricultural foodstuffs. The earlier experiences on environmental behaviour of artificial radionuclides helped greatly the management of the fallout situation after the Chernobyl accident in 1986. As a consequence of the accident, amounts of ^{137}Cs in natural produce vary largely still in 2000s. Indoor radon, however, is the greatest source of radiation exposure in Finland. Future challenges of radioecology at the national level are prioritised taking into account the basic need for new information and contribution to radiation safety, emergency preparedness, food safety and security research. Radiation protection of living organisms demands improvement of dosimetric models for risk assessment. Involvement of the stakeholders' opinions in practical work as well as in decision making is important. Maintenance and enhancement of competence in radioecology in the Europe-wide context including close cooperation both with national and international universities and research institutes, as well as networking and compiling all resources and expertise within the areas may be a new challenge also for STUK.

1. INTRODUCTION

STUK was established 50 years ago, in spring 1958. STUK had originally two operational areas: inspections of the radiation equipment used in hospitals, and research of fallout from nuclear weapon tests. From the start the main policy was to keep research and regulatory activities under the same roof. Monitoring of foodstuffs at STUK was started by milk monitoring in 1959 (^{89}Sr, ^{90}Sr and ^{137}Cs). Monitoring of radioactivity in deposition, lake and river waters and daily diets were initiated during 1961–1964. Simultaneously, first studies on food chain 'deposition-grass-milk' were performed followed by radioactivity analyses in tens of other plants. Research of radioactivity in the Baltic Sea environment started in close cooperation with the Finnish Marine Research Institute in the beginning of 1960s. STUK started marine studies in 1965 in the Loviisa area, the prospective site for the first NPP in Finland. At the same time, research of natural radioactivity, first in waters, and regular whole-body counting were launched. Continuous monitoring of airborne radioactivity at STUK was initiated at one station in 1967 and continued in later years with additional stations. Establishment of the Regional Laboratory of STUK in Rovaniemi, took place in 1970 to cover environmental monitoring and research in the Northern Finland.

2. ENVIRONMENTAL IMPACT OF MAN-MADE RADIOACTIVITY

Radioecological research focused first on environmental surveillance and effects of nuclear weapon tests in the Finnish environment and agricultural foodstuffs. Most of the monitoring programmes, started in early 1960s, are still continuing. Figure 1 shows the long-term trends of ^{137}Cs in ground level air and ^{90}Sr and ^{137}Cs in ground deposition in the Helsinki area from 1960s to the present day (Mustonen 2007). The impact of the nuclear weapon tests and the Chernobyl accident are clearly visible. As a general statement, we can say that the atmospheric nuclear tests in 1950s and 1960s had a stronger impact on

Article published by EDP Sciences and available at http://www.radioprotection.org
or http://dx.doi.org/10.1051/radiopro/20095112

the northern Finland, whereas the Chernobyl accident affected mainly the central and southern Finland. This is demonstrated by the Figures 2 and 3, showing the long term behaviour of ^{137}Cs in milk in northern Finland and south-western Finland (Kostiainen 2004), and the geographical distributions of plutonium isotopes and ^{137}Cs from the Chernobyl accident, respectively (Paatero et al. 2002, Arvela et al. 1990).

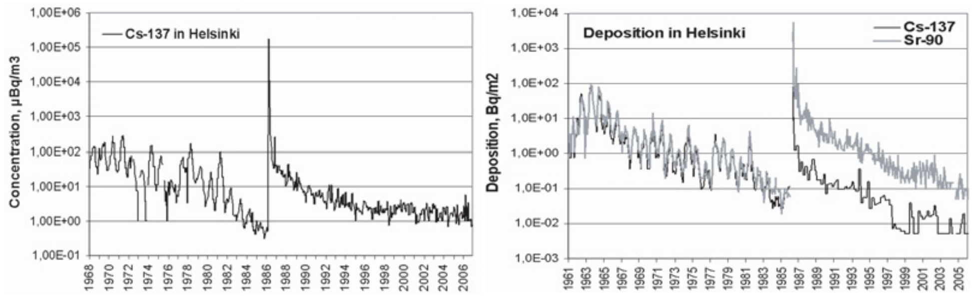

Figure 1. Long-term trends of ^{137}Cs in outdoor air and depositions of ^{137}Cs and ^{90}Sr in Helsinki.

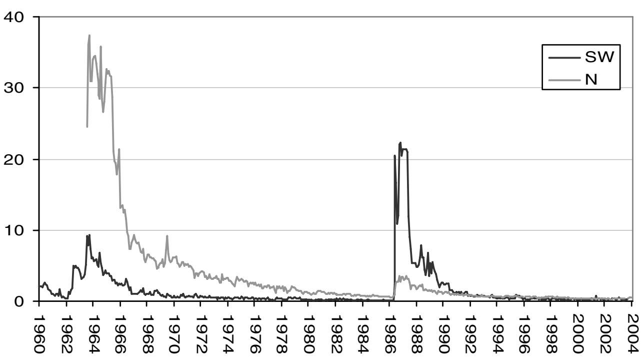

Figure 2. ^{137}Cs concentrations (Bq/l) in dairy milk in south-western (SW) and northern (N) Finland.

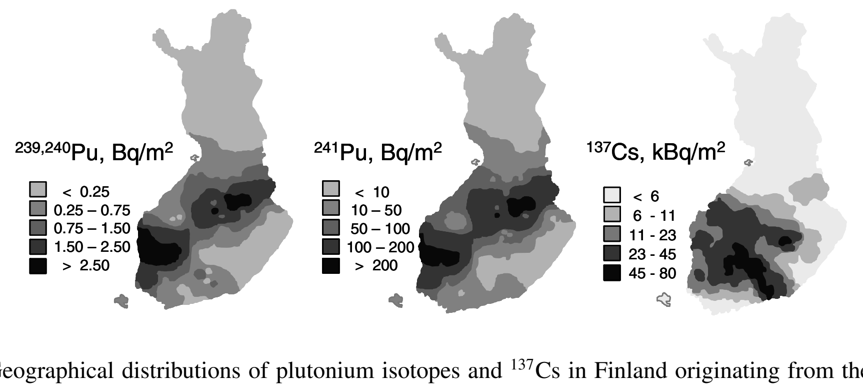

Figure 3. Geographical distributions of plutonium isotopes and ^{137}Cs in Finland originating from the Chernobyl accident.

An example on the versatile and detailed study on environmental radioactivity is the case of a fresh debris as early as in December 1966. Thorough analyses of fresh snow were made due to an unusual rise of radioactivity in the ground level air. The first gammaspectrometric measurements of fresh snow showed the presence of $^{140}Ba/^{140}La$. To identify other radionuclides, several radiochemical separations were performed from the snow. Radionuclides identified were ^{131}I, ^{132}Te and ^{132}I as well as ^{89}Sr, ^{90}Sr, ^{137}Cs, ^{141}Ce, and ^{140}Ba. Analyses of the deposition samples, collected at 17 stations, showed that the mean depositions of ^{90}Sr and ^{137}Cs for the whole country were 30 Bq/m^2 and 41 Bq/m^2 from this fallout. The absence of ^{95}Zr and ruthenium isotopes and the ratios of the identified nuclides referred to a leakage from e.g. an underground nuclear detonation. This fallout did not significantly contribute to the radiation exposure of the Finnish population. It was estimated that the maximum individual dose commitments from external exposure and internal exposure were about 4 μSv and 10 μSv, respectively (SFL, 1967).

Regular surveillance programmes of artificial radionuclides in the terrestrial and aquatic environments including foodstuffs were fixed in 1970s having continued with some modifications up to these days. The earlier experiences on environmental behaviour of important artificial radionuclides and preparedness to analyse alpha, beta and gamma emitters helped greatly the management of the fallout situation after the Chernobyl accident in 1986. Already in May 1986, STUK published two reports on the radiation situation in Finland (STUK, 1986a, STUK, 1986b). These reports and their rapid publication were widely appreciated internationally. After the accident, radioecological studies, especially in forest and semi-natural environments, were considerably increased. In natural environment, especially in mushrooms and freshwater fishes, the activity concentrations of ^{137}Cs increased much due to the deposition and the decrease is slow. In the areas of the highest Chernobyl deposition of ^{137}Cs in Finland, variation of ^{137}Cs in freshwater fishes is from a few becquerels to several thousand becquerels per kilogram fresh weight still in 2000s (Fig. 4) (Saxén, 2007). The highest values are found in predatory fishes in lakes characterized by e.g. low level of potassium and other nutrients in water, slow water exchange, low pH, low sedimentation rate and extended transfer from the catchment to the lake (Saxén and Ilus, 2008). Large variations of ^{137}Cs in mushrooms, detected still in 2000s, depend strongly on the species and quality of the growing area (Fig. 5) (Kostiainen, 2007). The limit for ^{137}Cs in natural produce on market, 600 Bq/kg f.w., recommended by the EU commission (2003/274/Euratom), may still be exceeded in case of mushrooms and freshwater fish. The Baltic Sea area received remarkable fallout of ^{137}Cs from the Chernobyl accident, making it to one of the most contaminated seas regarding ^{137}Cs. The radioactivity levels are still about 4 times higher in seawater and 100 times higher in sediments of the Gulf of Bothnia and the Gulf of Finland than before the accident (Vartti and Ikäheimonen, 2008).

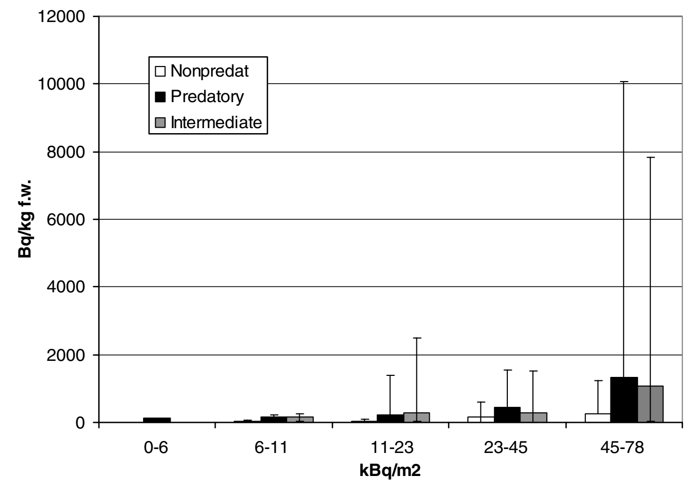

Figure 4. Average activity concentrations of ^{137}Cs with variation in three types of fishes: predatory, non-predatory and intermediate, in the areas with different levels of deposited ^{137}Cs in Finland in 2000s.

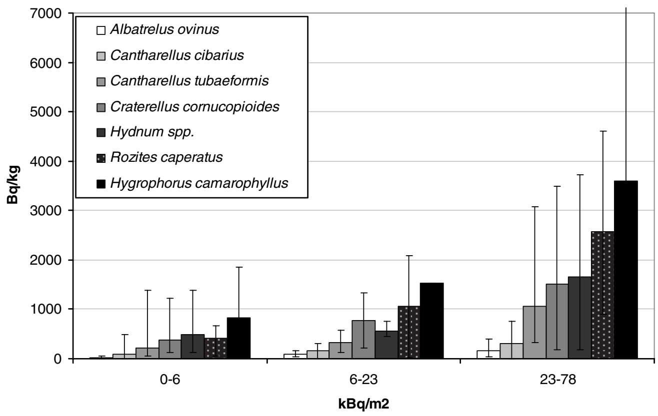

Figure 5. Average activity concentrations of ^{137}Cs with variation in various species of mushrooms, in the areas with different levels of deposited ^{137}Cs in Finland in 2000s.

3. STUDIES ON NATURAL RADIATION

The first indication of the fact that natural radionuclides might have some significance in environmental radiation was the finding of ^{222}Rn interfering with low level gammaspectrometric measurements in a STUK laboratory (Kahlos, 1969). Control measurements of water were started in order to study the source of radon in the laboratory. The later experiences have proved natural radionuclides in drinking water to be a major source of exposure to radiation in Finland (Asikainen, 1982, Vesterbacka, 2005). Table 1 shows the average effective doses from different radionuclides in drinking water from different water sources with the numbers of water users.

Table 1. Estimates on effective doses from different radionuclides in drinking water from different types of water sources, together with the number of water users.

Water source	Users	Rn-222 (mSv)	U-238 (mSv)	U-234 (mSv)	Ra-226 (mSv)	Pb-210 (mSv)	Po-210 (mSv)	Total (mSv)
Drilled wells	200000	0,29	0,008	0,014	0,010	0,022	0,046	0,39
Wells dug in soil	300000	0,032	0,001	0,001	0,003	0,007	0,007	0,05
Waterworks	4700000	0,02	0,0005	0,0008	0,0007	0,0015	0,003	0,02

In 1970's STUK started to investigate building materials as sources of indoor exposure to natural radiation (Mustonen, 1984) and occurrence of ^{222}Rn in indoor air (Arvela, 1995). Construction materials did not prove to be a remarkable source of radiation exposure, but soil and bedrock under houses turned out to be the greatest source of radiation exposure in Finland.

Radiological impact of uranium mining and milling was studied in late 1980s in the environment of former small uranium mines (Mustonen et al., 1990). Today interest in prospecting of uranium in Finland has increased again resulting in growing need of radioecological competence of naturally occurring radionuclides.

4. INTERNATIONAL CO-OPERATION

Nordic co-operation in radiation protection was initiated in 1958 after the first detections of the effects of the atmospheric atomic tests in the Northern hemisphere (Marcus, 1997). The fallout was of particular importance in the northern regions of Finland, Norway and Sweden due to high concentrations of radionuclides in lichen and its subsequent consumption by reindeer. Since those early days STUK has actively participated in the Nordic co-operation in radiation research, and especially in joint radioecological studies. The Nordic radioecological studies got more organised forms in 1977 when the first Nordic research framework programme was launched by the Nordic Committee for Nuclear Safety Research, NKS.

From 1994 STUK has participated in the European Research Framework programmes (FP4-FP7). Since then STUK has engaged in 60 EU-projects, ranging from network activities to large integrated projects. Four of them were co-ordinated by STUK, and 23 were related to radioecological studies. Future of the European radioecological research is discussed in the project FUTURAE of the EURATOM FP7 aiming to evaluate the future needs and priorities of radioecology at the European level.

Besides Nordic, European and bilateral co-operations, STUK has participated in global radioecological projects coordinated by the IAEA. After the Chernobyl accident STUK participated in a large project on validation of environmental model predictions (VAMP, BIOMOVS). Quite recently STUK has contributed to the project EMRAS (Environmental Modelling for Radiation Safety), including, among other things, updating of the report on transfer factors for various radionuclides, radioecological models and parameters for radiological assessments, and comparison of the methods for the estimation of radiation doses to biota. STUK has also given a strong contribution on developing quality assurance work internationally.

5. FUTURE CHALLENGES

Future challenges of radioecology at the national level are prioritised taking into account the basic need for new information and contribution to radiation safety, especially supporting research and filling data gaps in emergency preparedness, food safety and security in case of malevolent use of radionuclides. After the period of extensive studies on long-term behaviour of artificial radionuclides in the environment, the focus is turning more and more to natural radionuclides in the environment and foodstuffs. However, this must be done without losing touch with the long-term monitoring of artificial nuclides. The continuous monitoring and observations of time trends of the radioactive substances form the basis for knowing and understanding the state of radioactivity in the environment.

A new research field, radiation protection of living organisms, demands improvement of dosimetric models for risk assessment. Data is needed on many radionuclides in the habitat of organisms and in the organisms themselves. Lack of data in this field, especially on natural radionuclides, is worldwide.

Careful handling and storing of research and surveillance data to serve as a data bank for use of other scientists both now and in future offers a challenge for governmental institutes.

An increasing need for the interaction with stakeholders has been recognized also in the field of radiation protection. This has been carried out by regular questionnaires and cooperation meetings with national stakeholders according to the STUK quality management. Nevertheless, involvement of the stakeholders' opinions in decision making also forms a challenge in the future work.

Maintenance and enhancement of competence in radioecology in the Europe-wide context is a challenge including close cooperation both with national and international universities and research institutes. Networking and compiling resources, facilities and areas of expertise within the areas identified by European stakeholders, e.g. decision makers, legislators, regulators and industry, may be a new challenge also for STUK.

References

[1] Arvela H., Residential radon in Finland: Sources, variation, modelling and dose comparisons. STUK-A124. (Radiation and Nuclear Safety Authority, Helsinki, 1995).

[2] Arvela H., Markkanen M. and Lemmelä H., Mobile survey of environmental gamma radiation and fall-out levels in Finland after the Chernobyl accident. *Rad. Prot. Dosim.* **32** (1990) 177–184.

[3] Asikainen M., Natural radioactivity of ground water and drinking water in Finland. STL-A39. (Institute of Radiation Physics, Helsinki, 1982).
[4] Kahlos H., Radon-222 concentrations of some water samples determined with gammaspectrometric measurements. SFL-A14. (Institute of Radiation Physics, Helsinki, 1969).
[5] Kostiainen E., ^{137}Cs in Finnish wild berries, mushrooms and game meat in 2000–2005. *Boreal Env. Res.* **12** (2007) 23–28.
[6] Kostiainen E., "Ecological half-times of ^{137}Cs and ^{90}Sr in dairy milk in regions with different soil types", International conference on the scientific basis for environment protection against radioactivity, ECORAD 2004. Aix-en Provence, 6–10 September 2004. (2004).
[7] Marcus F.R., Half a Century of Nordic Nuclear Co-operation. An Insider's Recollections. (Nordisk Kernesikkerhedsforskning, Roskilde, 1997).
[8] Mustonen R., Natural radioactivity in and radon exhalation from Finnish building materials. *Health Phys.* **46** (1984) 1195–1203.
[9] Mustonen R. (ed), Surveillance of Environmental Radiation in Finland. Annual Report 2006. STUK-B 77. (Radiation and Nuclear Safety Authority, Helsinki, 2007).
[10] Mustonen R., Salonen L. and Ikäheimonen T.K., "Environmental condition and impact of an inactive uranium mine in Finland". The 9th annual meeting, Ronneby, Sweden, 29–31 August 1990 (Nordic Society for Radiation Protection, 1990).
[11] Paatero J., Jaakkola T. and Ikäheimonen T.K,. Regional distribution of Chernobyl-derived plutonium deposition in Finland. *J. Radioanal. Nucl. Chem.* **252** (2002) 407–412.
[12] Saxén R. ^{137}Cs in freshwater fish and lake water in Finland after the Chernobyl deposition. *Boreal Env. Res.* **12** (2007) 17–22.
[13] Saxén R. and Ilus., E., Transfer and behaviour of ^{137}Cs in two Finnish lakes and their catchments. *Sci. Total Environ.* **394** (2008) 349–360.
[14] SFL, 1967. Studies on environmental radioactivity in Finland 1966. Annual Report. SFL-A8. (Institute of Radiation Physics, Helsinki, 1967).
[15] STUK 1986a. Interim report on fallout situation in Finland from April 26 to May 4 1986, STUK-B-VALO 44 (Radiation and Nuclear Safety Authority, Helsinki, 1986).
[16] STUK 1986b. Second interim report on fallout situation in Finland from April 26 to May 4 1986, STUK-B-VALO 45 (Radiation and Nuclear Safety Authority, Helsinki, 1986).
[17] Vartti V-P, Ikäheimonen T.K., "Monitoring of radionuclides in the Baltic Sea in 2007" Project Group for Monitoring of Radioactive Substances in the Baltic Sea (MORS), HELCOM, 13th Meeting, St. Petersburg, Russia, 27–29 May 2008, *http://meeting.helcom.fi/c/document_library/get_file?folderId=89327&name=DLFE-33740.pdf,* June 2008.
[18] Vesterbacka P., ^{238}U-series radionuclides in Finnish groundwater-based drinking water and effective doses. STUK-A213 (Radiation and Nuclear Safety Authority, Helsinki, 2005).