FRÓÐSKAPARSETUR FØROYA

NVD Rit

SERRITGERÐ
Thesis

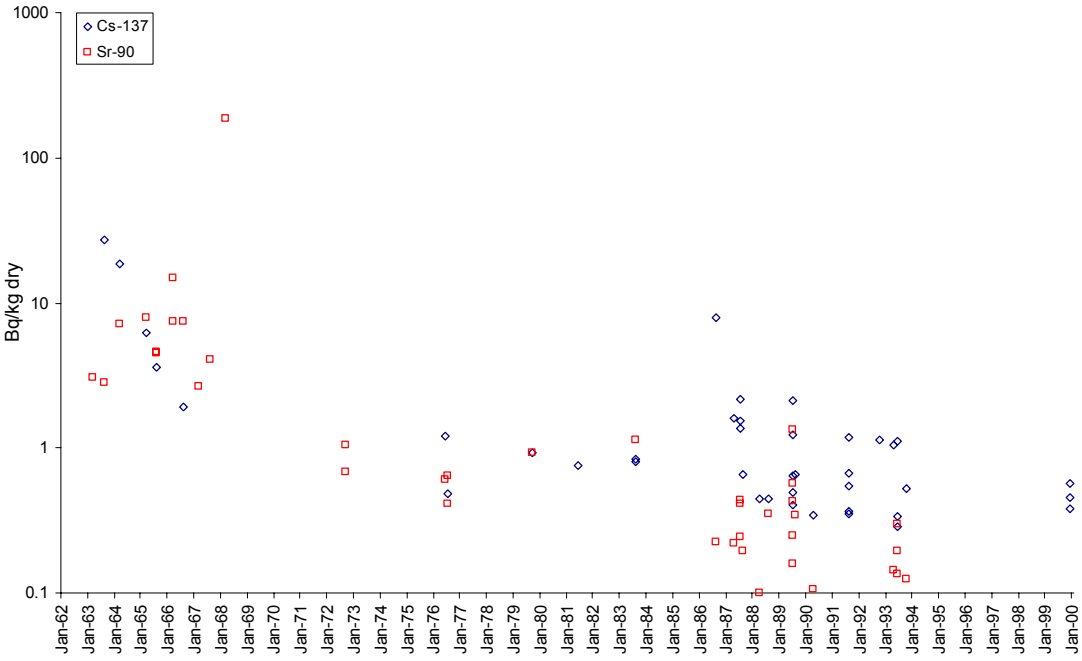
TØKNIFRÁGREIÐING
Technical Report

UNDIRVÍSINGARTILFAR
Teaching Material

UPPRIT
Notes

New indicator organisms for environmental radioactivity (INDOFERN). NKS-B Annual Report. Faroe Islands 2002

Hans Pauli Joensen



^{137}Cs and ^{90}Sr in Fucus sp. from the Faroe Islands 1962-2000

NVD*Rit* 2002:23

NÁTTÚRUVÍSINDADEILDIN
Faculty of Science and Technology

FRÓÐSKAPARSETUR FØROYA
University of the Faroe Islands

Heiti / Title New indicator organisms for environmental radioactivity (INDOFERN). NKS-B Annual Report. Faroe Islands 2002

Høvundur / Author Hans Pauli Joensen

Ritslag / Report Type Tøknifrágreiðing/Technical Report

NVD*Rit* 2002:23

Útgevari / Publisher Náttúruvísindadeildin, Fróðskaparsetur Føroya
Bústaður / Address Nóatún 3, FO 100 Tórshavn, Føroyar (Faroe Islands)
Postrúm / P.O. box 2109, FO 165 Argir, Føroyar (Faroe Islands)
✆ • 🖷 • @ +298 352550 • +298 352551 • nvd@setur.fo

New indicator organisms for environmental radioactivity (INDOFERN). NKS-B Annual Report. Faroe Islands 2002.

Hans Pauli Joensen, Faculty of Science and Technology, Nóatún 3, FO 100 Tórshavn, University of the Faroe Islands

1. Introduction

The report presents measurements of ^{137}Cs in bio-indicator organisms selected for the Faroese part of the INDOFERN project. Results are reported for moss and empetrum species from the terrestrial environment, Brown trout and lake water from freshwater environment, and Fucus vesiculosus and seawater from the marine environment. The samples were collected in the second half of year 2002.

Radioactivity measurements have been carried out for different Faroese environmental samples during the last four decades. There exist fairly good time series for ^{137}Cs and ^{90}Sr in Fucus sp. back to the early 1960's, and a few measurements of Mytilus edulis and Ascophyllum nodosum. There are only sporadic data on bio-indicator organisms from the freshwater and terrestrial environment; existing data on ^{137}Cs and ^{90}Sr are reported for trout and lake water, and for moss and lichen.

2. Material and methods

Fucus vesiculosus and seawater were sampled from the marine environment in June 2002. Brown trout and lake water was sampled from two freshwater lakes in September 2002, and Moss sp. and Empetrum sp. together with soil and mixed grass were sampled at the shores of the lakes. All water samples were 200 liter, and ^{137}Cs was measured on AMP (Ammonium Molybdo Phosphate) precipitate. Soil samples were taken with a corer with 5.7cm inner diameter, and a length of 10cm. Three cores were taken from a 0.25m^2 square at each shore. The cores were split up in an upper and a lower 5cm disc, and the three discs from each layer were pooled to one sample before measurements. Grass samples were cut from the 0.25m^2 squares used for the soil samplings. The ^{137}Cs acitivity concentrations were measured with high resolution gamma spectroscopy on a Ge detector.

Table 1. Bio-indicators identified in the database containing old measurements. Measured isotopes: **1)** ^{137}Cs, ^{134}Cs, ^{90}Sr, ^{40}K. **2)** ^{137}Cs, ^{90}Sr, ^{40}K. **3)** ^{137}Cs, ^{90}Sr.

	Marine			Freshwater		Terrestrial	
Bio indicator	Fucus species [1]	Mytilus edulis [1]	Ascophyllum nodosum [2]	Lake water [3]	Trout sp. [3]	Moss sp. [1]	Lichen [1]
Time covered	1963-66, '72, '76, '79, '81, '83, '86-93, '99	1981, '87, '99	1972, '89, '91	1987, '89, '91,'93, '99	1975-76	1967, '87, '89, '99	1967, '87, '99

Cs-137 and ^{90}Sr have been measured earlier in various bio-indicator organisms with different data coverage during time. Data from marine, fresh water and terrestrial environment have been compiled from old files (cf. Table 1). The measurements derive from a co-operation between Risø, Denmark, and various Faroese institutions.

The University of the Faroe Islands has been the Faroese partner since the early 1990's.

3. Results from earlier measurements

3.1. Marine environment

The marine bio-indicators from earlier measurements cover Fucus sp., Mytilus edulis and Ascophyllum nodosum. The samples have been collected at different sites in the Faroe Islands, but they do all refer to the same water mass.

3.1.1. Fucus sp.

The species are recorded as just Fucus sp. until 1968. It has been recorded as Fucus vesiculosus since 1972, except for 1986, when it was registered as Fucus serratus, and except for September 1972 and April 1987, when it was registered as Fucus distichus.

Cs-137 and ^{90}Sr has been measured in Fucus sp. since the early 1960's, but both isotopes have not been measured in every sample.

The ^{137}Cs activity concentration in Fucus sp. decreased with short effective ecological half-life during the first tree years of measurements, from 27.2 Bq·kg^{-1}dw in August 1963 to 1.9 Bq·kg^{-1}dw in August 1966. The level was constant around 1 Bq·kg^{-1}dw from the mid 1970's until 1986 when input from the Chernobyl nuclear accident caused the ^{137}Cs activity concentration to increase. It was 7.9 Bq·kg^{-1}dw in august 1986. The decrease in the ^{137}Cs concentration was faster after the Chernobyl accident than in the early 1960's. It had decreased to 0.7 Bq·kg^{-1}dw in August 1987, and the concentration level has changed only slightly since.

Cs-134 was measured in four Fucus samples after the Chernobyl accident, showing ^{134}Cs/^{137}Cs ratios of 0.453, 0.346, 0.480, 0.176 for samples collected 1 August 1986, 1 April 1987, 1 June 1987 and 17 July 1989, respectively.

The highest reported ^{90}Sr activity concentration was 186 Bq·kg^{-1}dw, recorded for March 1968, while the second highest value was 15 Bq·kg^{-1}dw, recorded for March 1966; i.e. about a factor of 10 below the maximum. Cs-137 was not measured in 1966 and 1968. Aarkrog & Lippert (1969) say about the maximum value in 1968 that "the extreme value in March is difficult to explain. August was in agreement with last year's observations." It has still not been possible to find an explanation for the recorded maximum. The ^{90}Sr activity was generally around the same level as the ^{137}Cs activity except for 1986-87 and thereafter, when the ^{137}Cs activity level is higher because of input from the Chernobyl nuclear accident.

3.1.2. Ascophyllum nodosum

Ascophyllum nodosum has been sampled in 1972, 1989 and 1991. The measurements are presented in Table 2. It has not been possible to explain the increasing trends in the activity concentrations.

Table 2. ^{137}Cs and ^{90}Sr in Ascophyllum nodosum. Values are given with 1 counting standard deviation where available. (ND: No Data)				
	^{137}Cs		^{90}Sr	
	Bq/kg dw	Bq/kg K	Bq/kg dw	Bq/kg Ca
1 Sept. 1972	ND	ND	0.68	50.0±16.5
1 April 1989	0.39±0.14	16.2	0.11±0.03	8.3±2.1
1 August 1989	0.60±0.09	23.8±3.40	ND	ND
1 May 1991	1.36±0.14	61.2	2.34±0.05	165.4±3.47

3.1.4. Mytilus edulis

Soft tissue from Mytilus edulis has been measured on three occasions, as presented in Table 3. The relatively high activity concentration of ^{137}Cs in July 1987 is due to input from the Chernobyl accident. Cs-134 was measured to 0.160 Bq·kg^{-1}dw in this particular sample, giving a ^{134}Cs/^{137}Cs ratio of 0.235.

Table 3. ^{137}Cs and ^{90}Sr in Mytilus edulis soft tissue. Values are given with 1 counting standard deviation where available. (ND: No Data)						
	^{137}Cs			^{90}Sr		
	Bq/kg fw	Bq/kg dw	Bq/kg K	Bq/kg fw	Bq/kg dw	Bq/kgCa
14 June 1981	0.0568±0.0170	ND	23.0	ND	ND	ND
1 July 1987	ND	0.6804±0.0782	86.2	0.0083±0.0035	0.0048±0.0020	5.68±2.39
7 Dec. 1999	0.0521±0.0164	0.1326±0.0418	21.6±6.79	ND	ND	ND

3.2. Freshwater environment

Tables 4 and 5 show existing data from the freshwater environment. The ^{134}Cs/^{137}Cs ratio for lake water in 1987 was 0.161 and 0.241 in Leitisvatn and Leynavatn, respectively. The corresponding ratio was 0.101 in Leitisvatn in 1989.

Table 4. Measurements of radiocesium in lake water after the Chernobyl reactor accident. All values are given in Bq/m^3. ND: No Data.							
	July 1987		July 1989		August 1991	June 1993	Sept. 1999
	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	^{137}Cs	^{137}Cs	^{137}Cs
Leitisvatn	1.60	9.94	0.63	6.23	6.24	6.24	ND
Leynavatn	0.90	3.74	ND	1.84	2.60	2.30	1.26
Toftavatn	ND	ND	ND	ND	ND	ND	4.17

Measurements of ^{137}Cs and ^{90}Sr in trout can be found in Table 5. The trouts from 1987 were catched in Leitisvatn, and they contained almost only radiocesium from the Chernobyl nuclear accident. The average ^{134}Cs/^{137}Cs ratio from 18 trouts was 0.377.

Table 5. Measurements of ^{137}Cs and ^{90}Sr in rainbow trout flesh (Salmo irideus) in the Faroe Islands (the site has not been registered). One trout from each of the years 1975 and 1976. In 1987, the data represent averages in flesh from 18 Brown trout (Salmo trutta) from the lake Leitisvatn.

1 August 1975				1 June 1976				July 1987	
^{137}Cs		^{90}Sr		^{137}Cs		^{90}Sr		^{134}Cs	^{137}Cs
Bq/kg fw	Bq/kg K	Bq/kg fw	Bq/kg Ca	Bq/kg fw	Bq/kg K	Bq/kg fw	Bq/kg Ca	Bq/kg fw	Bq/kg fw
0.78	196	0.17	207	0.45	126	0.22	207	42.4	115.4

3.3. Terrestrial environment

Cs-137 and ^{90}Sr in moss and lichen from 1967, 1987 and 1999 can be found in Tables 6-10. The particular moss and lichen species have not been registered in any case. The data show large differences between locations, which may be related to difference in soil conditions at the sites and difference in species. There exist, however, no data to support an explanation of the observed differences.

Cs-134 was measured in the moss sample from Tórshavn in 1987 with a $^{134}Cs/^{137}Cs$ ratio of 0.365, indicating that nearly all the radiocesium activity derived from the Chernobyl accident.

Table 6. Measurements of ^{137}Cs and ^{90}Sr in moss sampled in Tórshavn and Tvøroyri 1 April 1967. The moss species are not identified.

Tórshavn				Tvøroyri	
^{137}Cs		^{90}Sr		^{137}Cs	^{90}Sr
Bq/kg fw	Bq/kg K	Bq/kg fw	Bq/kg Ca	Bq/kg fw	Bq/kg Ca
2479	410700	220	6808	363	1110

Table 7. Measurements of ^{137}Cs and ^{90}Sr in moss sampled in Tórshavn and "4-5km from Tórshavn" 1 July 1987. The moss species are not identified.

Tórshavn		"4-5km from Tórshavn"		
^{134}Cs	^{137}Cs	^{90}Sr		
Bq/kg fw	Bq/kg fw	Bq/kg fw	Bq/kg dw	Bq/kg Ca
219	600	4.39	10.6	8745

Table 8. ^{137}Cs in moss sampled at lake Toftavatn 1 September 1999. The moss species are not identified.

Bq/kg fw	Bq/kg dw	Bq/kg K
270	300	134537

Table 9. Measurements of ^{137}Cs and ^{90}Sr in lichen sampled in Tórshavn and Tvøroyri 1 April 1967. The lichen species are not identified.

Tórshavn				Tvøroyri			
^{137}Cs		^{90}Sr		^{137}Cs		^{90}Sr	
Bq/kg fw	Bq/kg K	Bq/kg fw	Bq/kg Ca	Bq/kg fw	Bq/kg K	Bq/kg fw	Bq/kg Ca
3352	210900	816	12173	1221	235320	89.0	7141

Table 10. Measurements of ^{137}Cs and ^{90}Sr in lichen sampled "4-5km from Tórshavn" 1 July 1987. The lichen species are not identified.					
^{134}Cs	^{137}Cs		^{90}Sr		
Bq/kg dw	Bq/kg dw	Bq/kg K	Bq/kg fw	Bq/kg dw	Bq/kg Ca
341	852	595804	3.44	4.48	10080

4. Results from new measurements

New samplings have been carried out for the INDOFERN project in 2002.

4.1. Marine environment

Seawater and Fucus were sampled in June 2002. The ^{137}Cs activity concentrations are presented in Table 11.

Table 11. Activity concentration of ^{137}Cs in marine samples. Seawater activity is given with 1 counting standard deviation.			
Sampling site	Sampling date	Fucus vesiculosus	Seawater
Kirkjubøur	27 June 2002	<0.3 Bq/kg dw	1.85±0.14 Bq/m^3

4.2. Freshwater environment

Two lakes were selected for freshwater sampling. The results are presented in the following tables.

Table 12. ^{137}Cs in Brown trout (*Salmo trutta*) and lake water from the lakes Toftavatn and Leitisvatn in 2002. Trout were catched on 15 August in both lakes. Lake water was sampled on 3 September from Toftavatn and 6 September from Leitisvatn.						
Lake	Salmo trutta					Water
	Number of trout	Mean	St. dev	Min	Max	
		Bq/kg ww	Bq/kg ww	Bq/kg ww	Bq/kg ww	Bq/m^3
Toftavatn	9	9.88	4.20	5.85	19.8	5.51±0.32
Leitisvatn	10	5.31	1.99	4.02	10.7	3.45±0.27

Physical statistics about the trout in Table 12 can be found in Table 13. The relationship between live weight and length of trout is given by the power function $W=K \cdot L^x$, where W is the live weight and L is the length; K is a proportionality constant. For trout from Leitisvatn we get $K=13.0 \cdot 10^{-3}$ and x=2.90. It was not possible to make the corresponding fit for trout from Toftavatn, as no intestines were included with the trout samples.

Table 13. Length and live weight of Brown trout (*Salmo trutta*) from lakes Toftavatn and Leitisvatn. The trout are the same as in Table 12. (*) Without intestines.					
		Mean	St. dev	Min	Max
Toftavatn	Length (cm)	25.9	2.27	23.0	29.7
	Weight (g) (*)	148.9	42.7	97.7	216.0
Leitisvatn	Length (cm)	24.3	2.16	20.9	28.9
	Weight (g)	131.2	38.8	89.6	232.4

Physical data for the lakes can be found in Table 14.

Table 14. Topographic data about the lakes.				
	Altitude, m	Surface area, km^2	Max depth, m	Volume, m^3
Toftavatn	15	0.509	22	$2.11 \cdot 10^6$
Leitisvatn	32	3.42	59	$81.6 \cdot 10^6$

4.3. Terrestrial environment

The terrestrial samples were collected in August and September 2002. The samples were taken at the shores of the lakes used for freshwater samplings. The results can be found in Table 15. Moss sp. and Empetrum sp. were sampled at Toftavatn.

Table 15. Cs-137 in terrestrial samples taken in 2002 on the shores of lakes Toftavatn and Leitisvatn. Values are given with 1 counting standard deviation.						
	Sampling date	Soil		Mixed Grass	Empetrum Hermaphroditum	Hyloconium Splendens
		0-5cm	5-10cm			
		Bq/m^2	Bq/m^2	Bq/kg dw	Bq/kg dw	Bq/kg dw
Toftavatn	9 Sept.	1514±74	1619±66	97.8±9.49	17.8±1.66	77.5±4.37
Leitisvatn	6 Sept.	2106±99	1940±112	75.4±4.90	ND	ND

5. Discussion

5.1. Marine environment

Exponential curve fitting to the ^{137}Cs data from March 1963 to August 1966 and from August 1986 to April 1988 resulted in half-lives of 271 days (R^2=0.986) and 142 days (R^2=0.883), respectively, in Fucus sp. The shorter post-Chernobyl half-life is explained by the fact that the input from Chernobyl came as a short pulse, while the input to the atmosphere in the 1960's was distributed over a longer time scale. The ^{137}Cs activity concentration in seawater and in Fucus vesiculosus from Kirkjubø 27 June 2002 was measured to 1.85 Bq/m^3 and less than 0.3 Bq/kg dw, respectively. The ^{90}Sr and ^{137}Cs data do generally show similar trends, except for the early 1960's and 1986-87. There was no ^{90}Sr input from Chernobyl.

There are only few measurements of Ascophyllum nodosum and Mytilus edulis, and no time series exist for those species in Faroese waters. The measurements of soft tissue from Mytilus edulis do suggest it to be a suitable bio-indicator organism for radiocaesium. It is, however, not possible to make any such conclusion from existing radioactivity data on Ascophyllum nodosum, although it should be expected to be a suitable bio-indicator organism.

5.2. Freshwater environment

There are no pre-Chernobyl data for lake water in the Faroe Islands. The ^{137}Cs activity concentration in water from Leitisvatn decreased from 9.94 Bq/m^3 in 1987 to 3.45 Bq/m^3 in 2002. The ^{137}Cs activity concentration in water from Leynavatn decreased from 3.74 Bq/m^3 in 1987 to 1.26 Bq/m^3 in 1999; no other data are available from this lake. Lake water from Toftavatn has only been sampled in September 1999 and August 2002, showing ^{137}Cs activity concentrations of 4.17±0.11 Bq/m^3 and 5.51±0.32 Bq/m^3, respectively. An explanation factor for the unexpected trend in water from Toftavatn may be that the water has been sampled from different parts of

the lake the respective years, as the lake consists of a deeper and a shallower part that are relatively separated. The higher ^{137}Cs concentration in water from Toftavatn as compared with Leitisvatn may be explained by higher resuspension from sediments in Toftavatn, as this lake is much shallower and smaller than Leitisvatn.

There exists only two pre-Chernobyl samples of trout, but the specific sampling location has not been registered, making it impossible to compare the data with new measurements. Radioactivity measurements of trout from July 1987 showed a pronounced signal from Chernobyl in trout flesh. The radiocaesium content in trout from August 2002 was higher in Toftavatn than in Leitisvatn, which coincide with the activity concentrations in the lake waters.

5.3. Terrestrial environment

Measurements of ^{137}Cs and ^{90}Sr from April 1967 indicate a significant geographical variation of the activity concentrations in Moss sp. and Lichen sp. with lower activity in the southern part of the country (Tvøroyri) as compared with the central area (Tórshavn). The moss and lichen species are, however, not identified in the old data files, and there is neither any information about soil characteristics from the respective sampling sites that could assist to explain the observed differences. Measurements of radiocaesium in moss and lichen from July 1987 show a pronounced signal from the Chernobyl nuclear accident in both bio-indicators. The ^{137}Cs activity in moss at lake Toftavatn decreased from 600Bq/kg dw in July 1987 to 300 Bq/kg dw in September 1999 and further to 78 Bq/kg dw in September 2002.

6. Conclusion

As expected, the present study shows that Fucus vesiculosus is a suitable indicator organism for radioactivity in the marine environment, as it is reacting soon to contamination from particularly ^{137}Cs. It will be considered to make measurements of other radionuclides in Fucus vesiculosus, particularly ^{99}Tc in order to monitor a possible input of this radionuclide from Sellafield. Corresponding measurements should be carried out for seawater.

The study also shows that Brown trout is a suitable bio-indicator organism for the freshwater environment. These measurements should continue along with measurements of ^{137}Cs in water from the lakes. It will be considered to study the stomach content of the trout, as food intake is the most important factor in transfer of radionuclides to trout.

Empetrum hermaphroditum and Hyloconium splendens were selected as bio-indicator organism for the terrestrial environment as these species are very common in the terrestrial environment. They are suitable indicator organisms for the terrestrial environment, but it will be considered to include Lichen sp. to the terrestrial sampling programme.

7. Acknowledgements

The author wishes to thank Sven P. Nielsen and Henning Dahlgaard for their making old radioactivity measurements from the Faroese environment available from Risø.

Thanks are due to Johanna Zachariassen and Marjun Mortensen at the University of the Faroe Islands for their active work and engagement in the laboratory as well as in the field concerning new sampling for INDOFERN. Thanks are extended to the Nordic Nuclear Safety Research (NKS) for financial support.

8. References

Aarkrog, A., Lippert, J.: Environmental Radioactivity in the Faroes in 1968. Risø Report No. 202, July 1969.

Joensen, H. P., Vestergaard, T.: Radiocaesium in Faroese Lakes after the Chernobyl Accident. In proceedings from the sixth Nordic seminar on radioecology. Tórshavn, Faroe Islands, 14-18 June 1992 .

Risø Reports. Environmental Radioactivity in the Faroes 1962-1993. Risø Reports nos. 64, 86, 108, 131, 155, 181, 202, 221, 246, 292, 306, 324, 346, 362, 387, 404, 422, 448, 470, 488, 510, 528, 541, 550, 622 and 757.