NILU TR : 2/88

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ABSTRACT

A migration of ^{137}Cs from air to soil and vegetation after the Chernobyl accident is studied using the concentrations measured in the Gulsvik area in Norway. The major part of the ^{137}Cs deposition seems to be in the soil. An uptake of ^{137}Cs from soil to plants through their root system is not a rapid process. Only a few per cent of the deposition can be traced in plants. This seems to suggest that as far as ^{137}Cs is concerned, an effect of the Chernobyl releases is not an acute but a long-term phenomenon. The ^{137}Cs accumulation in soils is rather high but does not result in ^{137}Cs levels in plants and diet higher than acceptable in Norway.

1 INTRODUCTION

The reactor accident in Chernobyl on 26 April, 1986 caused a release of various radionuclides to the atmosphere. Since the accident happened, there has been a number of studies reported in the literature on the emissions of radionuclides (e.g. USSR State Committee on the Utilization of Atomic Energy, 1986), their atmospheric transport (e.g. Persson et al., 1986; Saltbones, 1986), and the contamination of soils, plants and human diet (Backe et al., 1986; Helsedirektoratets Rådgivende Faggruppe, 1986).

The radioactivity of the air at selected stations in Norway after the accident has been studied by Pacyna et al. (1986). The highest activities of several radionuclides in precipitation were measured in samples from Gulsvik. The estimated dry deposition at this and other stations was lower by two orders of magnitude, and therefore insignificant. Pacyna et al. (1986) concluded that it should be of interest to study the consequences of this highly contaminated precipitation to soil and plants.

The major objective of this work was to study the ^{137}Cs migration from the air via precipitation to soil and plants in Gulsvik. The ^{137}Cs migration through the environment is presented in Figure 1. In this report the ^{137}Cs activities are presented together with the transport coefficients. In addition the ^{134}Cs activities were also measured to assess to what extent the Chernobyl releases have contributed to the ^{137}Cs accumulation in soil and plants.

2 EXPERIMENTAL

All samples were collected at seven locations (I to VII) in Gulsvik in August 1987 (see Figure 2). The locations I-IV were on agricultural land (cultivation of hay on moraimic till), V and VI were forest clearings at higher altitudes, and location VII was a small peat bog. As the half life of ^{134}Cs is only 2.06 years, the radioactive decay has been taken into account.

The details of sampling of soil and plants are presented in Tables 1 and 2. The samples of vegetation were collected from the same plot as the soil sample, dried, homogenized, weighted and analysed, as indicated in "Remarks" of Tables 1 and 2.

The radioactivity measurements were carried out at the Institute for Energy Technology (IFE) at Kjeller. All samples were analysed by gamma spectrometry with the use of a large Ge(Li) detector, a 4096 channels MCA, and computerized spectrum analysis. The system has been duly calibrated using certified standards of ^{134}Cs and ^{137}Cs.

3 RESULTS

The ^{134}Cs and ^{137}Cs concentrations in soil and plant samples collected at locations I, II, III, IV, V and IV are presented in Table 3. The ^{134}Cs and ^{137}Cs concentrations in a peat bog sample taken at Gulsvik are shown in Figure 3.

Finally, the $^{137}Cs/^{134}Cs$ ratios were calculated for all samples and these are presented in Figure 4.

4 DISCUSSION

There are three major pathways for atmospheric ^{137}Cs to contaminate plants and later human diet: 1) deposition on soil and uptake by the plant root system, 2) direct deposition on pasture grass and 3) direct deposition on the above-surface food crops. The two first pathways are discussed in this work.

4.1 CONTAMINATION OF LAND

Based on the previous work (Pacyna et al., 1986), a precipitation of 4.4 mm during 28-29 April, 1986 at Gulsvik contributed 5.8 $kBq \cdot m^{-2}$ of ^{137}Cs. Dry deposition of ^{137}Cs was found insignificant. The inferred deposition of ^{137}Cs and ^{134}Cs from soil samples at 6 locations were from 3.6 to 75.2 $kBq \cdot m^{-2}$ (Table 4). There are substantial differences between the amounts of ^{137}Cs and ^{134}Cs deposited at the different sites within only 1-2 km.

It should be noted, however, that the ^{137}Cs deposition measured at the sampling sites within the farm (I, III and IV) was comparable with the data from precipitation measurements. Concerning outfield soil samples, much higher amounts of ^{134}Cs and ^{137}Cs suggest that the deposition must have been considerably larger at higher elevations during this particular event.

It was interesting to assess to what extent the Chernobyl releases of ^{137}Cs have contributed to the total deposition of the radionuclide in soil within a 20 cm plough layer of soil. For this purpose ^{134}Cs measurements were carried out and it was assumed that the $^{134}Cs/^{137}Cs$ ratio in the Chernobyl releases was 0.5. Clough (1986) indicates that the $^{134}Cs/^{137}Cs$ ratios measured in a wide range of samples from the dispersed radioactivity, both within and outside the Soviet Union fall in the range 0.4 to 0.6. Thus, it is assumed here, that the ratio 0.5 may be representative. As the half-life time of ^{134}Cs is only 2 years it is reasonable to suggest that all the deposited ^{134}Cs was due to the Chernobyl releases, and is not a result of nuclear bomb tests in the early 1960´s. As can be seem from Table 4, 80% or more of ^{137}Cs in soil at all locations in this work except location IV can be related

to the releases of the radionuclide after the Chernobyl accident. Location IV is in the agricultural land near location III. It is difficult to explain why the ^{134}Cs at location IV is significantly lower than at the other locations. One explanation can be that the old ^{137}Cs has been kept in "agricultural" land closer to the surface and more available than in "natural" locations. The other explanation could be a measurement error.

The ^{137}Cs and ^{134}Cs deposition data in Table 4 can be compared with other measurements in Norway. According to Backe et al. (1986) the average deposition for various counties ("fylker") in Norway after Chernobyl ranged from 0.17 $kBq \cdot m^{-2}$ (Troms) to 15.0 $kBq \cdot m^{-2}$ (Oppland) for ^{134}Cs, and from 0.33 $kBq \cdot m^{-2}$ to 28.0 $kBq \cdot m^{-2}$ for ^{137}Cs. The average values for Norway were 3.7 $kBq \cdot m^{-2}$ for ^{134}Cs and 7.1 $kBq \cdot m^{-2}$ for ^{137}Cs with the $^{134}Cs/^{137}Cs$ ratio of 0.52. The highest ^{134}Cs and ^{137}Cs deposition was measured in Øystre Slidre municipality in Oppland being in average 52.3 and 103.5 $kBq \cdot m^{-2}$, thus twice as much as the highest activities at location VI in this work.

The major part of the ^{134}Cs and ^{137}Cs depositied was found in the soil top layer <10 cm, as shown in Figure 3. Then the concentrations have decreased with depth but ^{137}Cs was still measurable at 25 cm due to fallout. The $^{137}Cs/^{134}Cs$ ratio ranges from 2 to 3 (Figure 4) indicating that most of the ^{137}Cs measured down to 25 cm depth was due to the radionuclide releases after the Chernobyl reactor accident.

4.2 CONTAMINATION OF PLANTS

A part of the radionuclides in the agricultural land can be transferred to plants via its root system. Eriksson (1986) has suggested that before the hay harvest in June about 50% of a deposition on agricultural land may be intercepted by the growing crops. Fortunately, as the Chernobyl fallout occured in April, the result was less devastating.

The ^{137}Cs activities in various plants growing at the locations where the soil samples were collected are shown in Table 5. The ^{137}Cs activities in the hay samples are also presented. The ^{137}Cs activity range for grass is 0.24 to 0.70 $kBq \cdot kg^{-1}$ dry matter and can be compared to

0.3-4.3 $kBq \cdot kg^{-1}$ for the sum of ^{134}Cs and ^{137}Cs measured by SIS in Oppland (Helsedirektoratets Rådgivende Faggruppe, 1986). The ^{137}Cs activities in the hay samples in this work were somewhat lower than in the grass samples, while higher for the litter and moss samples. However, the ^{137}Cs content of hay has never exeeded 4 $kBq \cdot kg^{-1}$ which corresponds to a ^{137}Cs level of 370 Bq in 1 kg of cow´s milk.

Eriksson (1986) suggested that even lower levels, in the range 1-2 $kBq \cdot kg^{-1}$ of hay, would be enough to yield contents of ^{137}Cs in milk and especially in meat, which were unacceptable to the consumers. It should be noted that the Swedish action level of 370 $Bq \cdot kg^{-1}$ was established for ^{137}Cs in all foods, while Norway had a $^{134}Cs + ^{137}Cs$ action level of 370 $Bq \cdot kg^{-1}$ for milk and baby food, and 600 $Bq \cdot kg^{-1}$ for all other foods; and later (autumn 1986) even 6000 $Bq \cdot kg^{-1}$ for reindeer meat and 6000 $Bq \cdot kg^{-1}$ for freshwater fish. The maximum values observed during this experiment where those for hay from the storage (location II) and reached only about 0.6 $kBq \cdot kg^{-1}$.

The ^{137}Cs transport to plants can be discussed on the basis of various factors. Transport coefficients and transfer factors are shown in Table 5. The transport coefficient is the ratio of the cesium content in 1 kg dry matter to the deposition of the radionuclide per 1 m^2. The transfer factor is the ratio between the activity of 1 kg harvested material and the activity of 1 kg dry soil in a plough layer of 20 cm (Eriksson and Rosen, 1987). The transport coefficients and transfer factors in Table 4 vary by a factor of 10. To explain the variability in the transport and migration, differences in both soil conditions and in plant growth conditions should be considered. Cesium is similar to potassium in ion radius, and potassium competes with cesium both with respect to soil cation exchange saturation and root uptake by plants. Eriksson and Rosen (1987) found that soil exchangeable potassium reduced the uptake of cesium in plants, while organic matter increased the uptake. Glowiak and Pacyna (1978) found, however, that soils rich in humus allow higher dosages of ^{137}Cs than light, or sandy soils. These findings can be reconciled, under the condition that the Polish soils rich in humus also contain more exchangeable cations than the light and sandy soils, while the opposite may be true for the Swedish soils with high organic content relative to clay soils with less organic material.

Uptake by plants also depends on plant growth conditions, particularly where migration coefficients are considered. Growth conditions on sites III and IV were probably limited by soil conditions.

If organic matter is high, it is another matter. It is also possible that high organic matter influences growth conditions and thereby plant-uptake.

The other method to express the ^{137}Cs migration from soil to plants is the use of a migration coefficient, which relates the ^{137}Cs content of plants collected from the area of 1 m^2 to the ^{137}Cs content of soils in 1 m^2 and 20 cm depth. Thus, the migration coefficient tells what part of the deposition is contained in plant. The migration coefficients calculated in this work are presented in Table 6. They indicate that in total only ca. 4 per cent of the deposition was contained in hay, 1 to 9 per cent in grass and 1 to 10 per cent in litter and mosses. Concerning grass samples, those grown on agricultural land (locations III and IV) have significantly higher migration coefficients than those from natural land (7-9 vs. 1-1.5).

Eriksson (1986) concluded that only 3 per cent of the ^{137}Cs deposition was still contained by the whole vegetation cover at the end of June 1986 in Middle Sweden where the heaviest depositions of radioactivity had taken place after the Chernobyl reactor accident.

4.3 PREDICTED CONTAMINATION OF MILK, MEAT AND DIET

Pasture grass contamination results in a transport of ^{137}Cs to milk and meat (Figure 1) according to:

$$C_{milk} = TC_1 \cdot C_{grass} \qquad (1)$$

and

$$C_{meat} = TC_2 \cdot C_{grass} \qquad (2)$$

where C is the ^{137}Cs concentration and TC is the transport coefficient. The TC has been presented by the International Commission on Radiological Protection (ICRP) in a report on the effects of radionuclide release into the environment and the assessment of doses to man (ICRP, 1979). The TC coefficients are shown in Table 7. These coefficients were used to predict the contamination of milk and beef meat in the Gulsvik area on the basis of the ^{137}Cs concentrations in pasture grass. The results are shown in Table 8. Concerning milk, the predicted ^{137}Cs concentrations are lower than the suggested 370 $Bq \cdot l^{-1}$ (as already mentioned) unless the maximum TC value is used. It should be mentioned, however, that in general, the observed TC values are lower than the nominal values. The Directorate of Public Health has presented a report (Helsedirektoratet, 1986) on the radiactivity level in various food and environmental media after the Chernobyl accident indicating that the $^{137}Cs + ^{134}Cs$ concentrations in cow's milk from dairies were up to 50 $Bq \cdot l^{-1}$ and in goat's milk up to 600 $Bq \cdot l^{-1}$. The ^{137}Cs concentrations in milk predicted in this work can be regarded as higher than measured in Norway after the Chernobyl releases. Unfortunately, the ICRP values of transport coefficients are not explained whether they are related to cow's milk or goat's milk (most probably cow's milk). The amounts of $^{137}Cs + ^{134}Cs$ in goat's milk being sold to the customers were below 200 $Bq \cdot l^{-1}$. The ICRP nominal value of the transport coefficient from pasture grass to milk seems to be at least two times higher than the transport coefficient that has been used in this work. This means that the transport coefficient from pasture grass to milk will be 0.2 $m^2 \cdot l^{-1}$ in this work.

The Directorate of Public Health reports on very high concentrations of ^{137}Cs in wild reindeer, up to 70 000 $Bq \cdot kg^{-1}$ compared to the action level of 6 000 $Bq \cdot kg^{-1}$ (Helsedirektoratet, 1986). When this kind of meat is not considered, the total ^{134}Cs and ^{137}Cs concentrations measured in beef meat in most parts of the country were generally lower than 600 $Bq \cdot kg^{-1}$. The predicted values can be compared with the ^{137}Cs content of beef meat ("storfekjøtt") being 100 $Bq \cdot kg^{-1}$. This may suggest that the transport coefficient from pasture grass to beef in this work is twice as high as the nominal value from ICRP (1979), thus 0.2 $m^2 \cdot kg^{-1}$.

Consumption of milk and meat is the major intake route of ^{137}Cs to the human body, contributing about 76 per cent to the individual dose of the radionuclide in Norway. It can be assumed that the transport coefficients for milk and meat are 0.2 $m^2 \cdot kg^{-1}$ and the yearly average consumption of milk and meat is 240 kg and 62 kg, respectively (Helsedirektoratet, 1986). Thus the yearly intake of ^{137}Cs from milk and meat based on the Gulsvik data would be in the range of 8 to 50 kBq and the total ^{137}Cs intake from 10 kBq to 60 kBq. This will correspond to individual doses in the range 0.15 to 0.9 mSv per year. The average values for Norway are calculated to be 0.2 mSv per year for low consumption of reindeer meat and 3.3 mSv per year for high consumption of reindeer meat (Helsedirektoratet, 1986). Thus, it can be concluded that the predicted values in this work are in good agreement with these official data from Norway.

4.4 COMPARISON OF THE DATA COLLECTED IN THIS WORK TO THE ^{137}Cs CONCENTRATIONS MEASURED AFTER THE NUCLEAR BOMB TESTS IN THE 1960´s

A comparison of the ^{137}Cs measurements in precipitation, soil and grass samples from Uppsala (1966-1967), Wroclaw, Poland (1972-1975) and Gulsvik (this work) is given in Table 9. It has already been indicated that the ^{137}Cs deposition in the mostly affected regions in Norway after the Chernobyl reactor accident was about three orders of magnitude higher than the ^{137}Cs deposition measured after the nuclear bomb tests in the early 1960´s (Pacyna et al., 1986). This is also valid for the ^{137}Cs contamination of grass as can be seen from Table 9. Interestingly, the soil contamination after the Chernobyl accident is even more pronounced than the grass contamination.

It should be admitted, however, that the above comparison needs to be done with some caution. The soil condition can be quite different in the compared regions. Besides, the collection of samples and analytical techniques were also different, influencing the above comparison.

5 CONCLUSIONS

The ^{137}Cs measurements in soil and plant samples from Gulsvik can be used to assess the migration of the radionuclide in the Norwegian environment after the Chernobyl reactor accident. The major part of the ^{137}Cs deposition seems to be in the soil. An uptake of ^{137}Cs from soil to plants through their root system is not an efficient process. Only a few per cent of the deposition can be traced in plants. This seems to indicate that as far as ^{137}Cs is concerned, the effect of the Chernobyl releases is not an acute but a long-term phenomenon. The ^{137}Cs accumulation in soil is rather high but does not result in ^{137}Cs levels in plants and diet higher than acceptable in Norway. In this connection the effect of the Chernobyl accident might have been much worse if it had happened in June. Then the direct deposition on plants almost ready for harvest would result in a much more serious contamination of the human diet and body by ^{137}Cs.

The results of this study were used to calculate various transport coefficients for ^{137}Cs and to compare these coefficients with coefficients calculated in the 1970´s (e.g. Pacyna, 1975). Generally, the Chernobyl releases of ^{137}Cs caused an increase of the amount of this radionuclide in the Norwegian environment by more three orders of magnitude, but did not seem to change the migration scheme of ^{137}Cs through the individual environmental media. The uptake of the radionuclide from soil to plants is as low as it used to be, and so is the transport from plants to milk and meat. Thus, the major contributor of ^{137}Cs in grass and hay is direct deposition on their leaves. Pacyna (1975) concluded that this contribution is as high as 70% while the rest is through the root system. It is difficult to ascribe any numbers to the Gulsvik ecosystem in this connection, but the principle of low ^{137}Cs migration through the root has been confirmed.

7 ACKNOWLEDGEMENT

The authors thank Drs. Brit Salbu of Agricultural University of Norway and Brynjulf Ottar and Jørgen Schjoldager of NILU for very valuable comments.

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Table 1: Information about soil sampling.

Location	Sample No..	Depth, cm	Sampling area (cm x cm)	Weight, g dry matter	Remarks
			Peat bog samples		
	1	0-4	17 x 17	255	1) A sample of mosses (No. 48 in Table 2) was collected from the top of the soil. 2) Natural environment.
	2	4-5	17 x 17	169	
	3	5-7	17 x 13	216	
	4	7-9	17 x 13	307	
	5	9-10	17 x 13	238	
	6	10-11.5	17 x 13	259	
	7	11.5-13	17 x 13	351	
	8	13-14.5	17 x 13	354	
VII	9	14.5-16	17 x 13	508	
	10	16-17	16 x 12	352	
	11	17-18	15 x 16	281	
	12	18-19	15 x 16	308	
	13	19-20	15 x 16	311	
	14	20-21	14 x 16	301	
	15	21-22	14 x 16	366	
	16	22-23	14 x 15	302	
	17	23-24	14 x 15	190	
	18	>24	14 x 15	755	
	19	0-5	18 x 16	230	1) Agricultural land used for hay. 2) 5 samples of hay (No. 31-35) were collected from this field.
I	20	5-20	18 x 16	650	
	21*	0-2.5	18 x 16	744	1) A sample of grass (No. 41) was collected from the top of soil. 2) Agricultural land.
III	22	2.5-5.0	18 x 16	452	
	23	5-15	7 x 8	602	
	24*	0-4	18 x 17	853	1) A sample of grass (No 42) was also collected. 2) Agricultural land.
IV	25	4-8	18 x 17	1207	
	26*	0-2.5	17 x 17	849	1) 4 samples of various plants (No. 43-46 in Table 2) were collected nearby the soil sample 26. 2) Natural environment.
	27	2.5-7	17 x 17	1162	
V	28	>7	17 x 17	1414	
	29	0-7	17 x 17	554	1) A sample of grass (No. 47) was collected. 2) Natural environment.
VI	30	>7	17 x 17	314	

* The samples were divided into two parts to differentiate between the layer of some rests of plants on the top layer of soil and the soil itself.

Table 2: Information about vegetation samples.

Location	Sample No.	Type of plant	Sampling area (cm x cm)	Weight, g dry matter	Remarks
I	31	Hay		15	1) Soil sample No. 19 from Table 1.
	32	"		10	
	33	"		12	
	34	"		13.5	
	35	"		13	
II	36	Hay		17	These samples were taken from the storage room.
	37	"		16	
	38	"		13.5	
	39	"		12	
	40	"		14	
III	41	Grass	18 x 18	13	Soil sample No. 21
IV	42	Grass	17 x 18	13	Soil sample No. 24
V	43	Litter and mosses	17 x 17	11	Samples collected in the same area as the soil sample No. 26.
	44	Litter and mosses	17 x 17	15	
	45	Mosses	30 x 30	16	
	46	Grass	17 x 17	17	
VI	47	Grass	17 x 17	14	Soil sample No. 29.
VII	48	Mosses	17 x 17	10	Soil sample No. 1.

Table 3: Concentrations of ^{134}Cs and ^{137}Cs in samples of soil and vegetation (in $Bq \cdot g^{-1}$).

Sample site	Sample no.	Sample type	^{134}Cs		^{137}Cs	
			Concentration	Counting error %	Concentration	Counting error %
	1		0.47	± 5.8	1.67	± 2.1
	2		0.45	± 12.3	1.53	± 4.9
	3		0.34	± 14.9	1.11	± 5.7
	4		0.17	± 32.3	0.75	± 8.9
	5		0.09	± 17.0	0.39	± 4.8
	6		-		0.24	± 18.2
	7		0.02	± 40.9	0.14	± 7.9
VII	8	Soil	-		0.08	± 45.3
	9		0.02	± 34.0	0.07	± 10.4
	10		-		-	
	11		0.03	± 43.2	0.09	± 15.2
	12		-		0.03	± 44.6
	13		-		0.04	± 26.2
	14		-		0.02	± 76.1
	15		-		-	
	16		-		0.02	± 45.7
	17		-		-	
	18		-		0.02	± 47.5
I	19	Soil	0.06	± 14.6	0.17	± 7.4
	20		0.01	± 48.6	0.05	± 14.2
	21a		1.37	± 6.9	3.95	± 4.6
III	21b	Soil	0.04	± 23.5	0.15	± 7.5
	22		0.01	± 25.8	0.04	± 6.5
	23		-		0.01	± 20.5
	24a		-		-	
IV	24b	Soil	0.02	± 26.0	0.08	± 5.2
	25		-		0.03	± 6.9
	26a		0.31	± 2.8	0.92	± 1.4
V	26b	Soil	0.11	± 5.3	0.39	± 3.3
	27		0.02	± 8.4	0.08	± 4.1
	28		0.01	± 62.8	0.02	± 21.1
VI	29	Soil	0.85	± 6.2	2.72	± 3.1
	30		0.03	± 28.7	0.17	± 8.0
	31		0.06	± 35.7	0.14	± 11.0
	32		0.10	± 19.5	0.30	± 7.7
I	33	Hay	0.05	± 65.7	0.11	± 35.3
	34		0.09	± 21.7	0.22	± 15.8
	35		0.05	± 32.8	0.09	± 18.5
	36					
	37		0.16	± 7.6	0.59	± 3.1
II	38	Hay	0.15	± 10.0	0.47	± 4.5
	39		0.14	± 12.7	0.39	± 5.5
	40		0.16	± 11.4	0.42	± 6.8
III	41	Grass	0.22	± 15.4	0.68	± 5.8
IV	42	Grass	0.25	± 5.7	0.70	± 3.3
	43	Litter & mosses	0.22	± 19.0	0.65	± 6.9
V	44	Litter & mosses	0.64	± 6.1	1.71	± 3.8
	45	Mosses	0.28	± 3.0	0.83	± 1.3
	46	Grass	0.08	± 19.6	0.24	± 10.8
VI	47	Grass	0.52	± 3.8	1.61	± 1.6
VII	48	Mosses	1.15	± 5.9	4.10	± 2.7

In addition to the counting error (2σ) in Table 3, 5% calibration standard uncertainty must be accounted for.

Table 4: Deposition of ^{137}Cs and ^{134}Cs at various locations.

Location	Measured deposition*3, kBq·m^{-2}		Fraction of ^{137}Cs*1 from Chernobyl	
	^{137}Cs	^{134}Cs	kBq·m^{-2}	%
I	2.4	1.2	2.3	96
III	4.6	1.8	3.6	80
IV	3.5	0.6*2	1.3	37
V	15.8	6.5	13.1	83
VI	52.1	23.1	43.2	89
VII	14.8	5.9	11.8	80

*1 Assuming the $^{134}Cs/^{137}Cs$ ratio of 0.5.
*2 Measurement error cannot be excluded.
*3 Soil only.

Table 5: Transfer of ^{137}Cs to plants on the basis of transport coefficients and transfer factors.

Location	Plant type	^{137}Cs content of plant kBq·kg^{-1} dry matter	Transport coefficient (TC) m^{2}·kg^{-1} dry matter	Transfer factor (TF)
I	hay	0.142	0.059	1.8
	hay	0.302	0.126	3.8
	hay	0.113	0.047	1.4
	hay	0.217	0.090	2.8
	hay	0.089	0.037	1.1
	average hay	0.170	0.071	2.2
III*1	grass	0.683	0.149	9.0
IV*1	grass	0.702	0.203	13.3
V	long litter and mosses	0.654	0.041	4.8
	long litter and mosses	1.705	0.107	12.5
	mosses	0.827	0.052	6.0
	grass	0.244	0.015	1.8
VI	grass	1.610	0.031	1.1
VII	mosses	4.103	0.278	9.6

*1 Very low data for soil have resulted in very high transfer factor value.

Table 6: Transfer of ^{137}Cs to plants on the basis of migration coefficients.

Locations	^{137}Cs in soil $kBq \cdot m^{-2}$	Plants		Migration coefficient K %
		Type	^{137}Cs content, $kBq \cdot m^{-2}$	
I	2.41	hay	0.09	3.7
III	4.57	grass	0.34	7.4
IV	3.45	grass	0.30	8.7
V	15.80	long litter and mosses	0.25	1.6
		long litter and mosses	0.30	1.9
		mosses	0.15	1.0
		grass	0.14	0.9
VI	52.14	grass	0.80	1.5
VII	14.76	mosses	1.42	9.6

Table 7: Transport coefficients from pasture grass to milk (TC_1) and meat (TC_2) after (ICRP, 1979).

Coefficient	Unit	ICRP nominal value	Observed range in other literature
TC_1	$m^2 \cdot l^{-1}$	0.38	0.12-2.1
TC_2	$m^2 \cdot kg^{-1}$	0.10	0.034-0.21

Table 8: Predicted ^{137}Cs contamination of cow milk and beef meat in the Gulsvik area.

Location	^{137}Cs concentration, when TC nominal used		^{137}Cs concentration, when TC_{max} used	
	milk, $Bq \cdot l^{-1}$	beef meat, $Bq \cdot kg^{-1}$	milk, $Bq \cdot l^{-1}$	beef meat, $Bq \cdot kg^{-1}$
III	129	34	714	71
VI	114	30	630	63
V	53	14	294	29
VI	304	80	1680	168

Table 9: ^{137}Cs concentrations in precipitation, soil and grass measured in Uppsala (1966-1967), Wroclaw, Poland (1972-1975) and Gulsvik (this work).

Site	Author	^{137}Cs concentration		
		Precipitation kBq·m^{-2}	Soil Bq·m^{-2}	Grass Bq·kg^{-1} dry matter
Uppsala (1966-1967)	Eriksson, 1976	0.02-0.06		3.7-18.5
Wroclaw, Poland (1972-1975)	Pacyna, 1975	0.001-0.01	0.7-2.7	1.5
Gulsvik	(this work)	5.85	2410-52100	244-1610

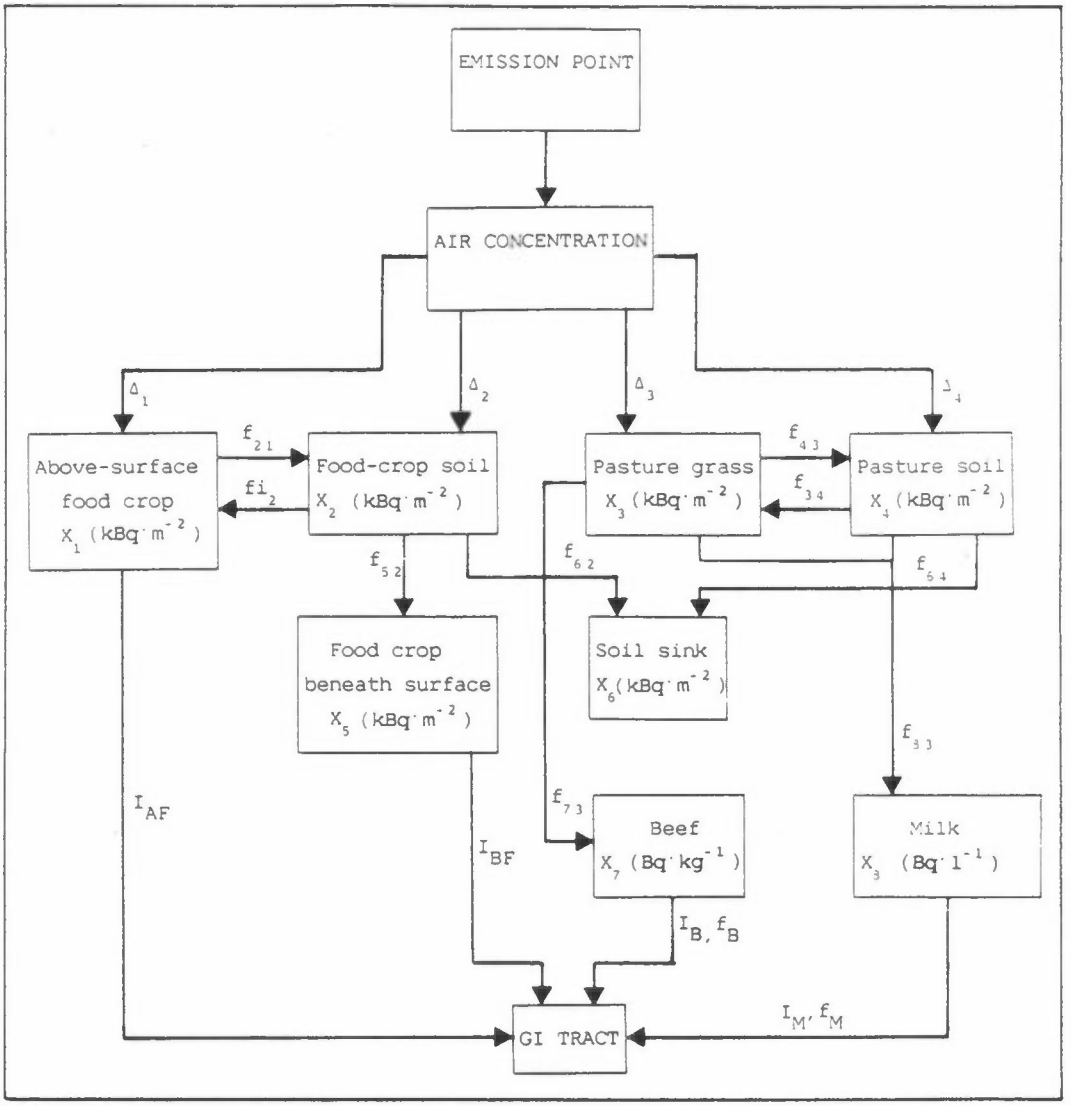

Figure 1: Migration of ^{137}Cs in the environment.

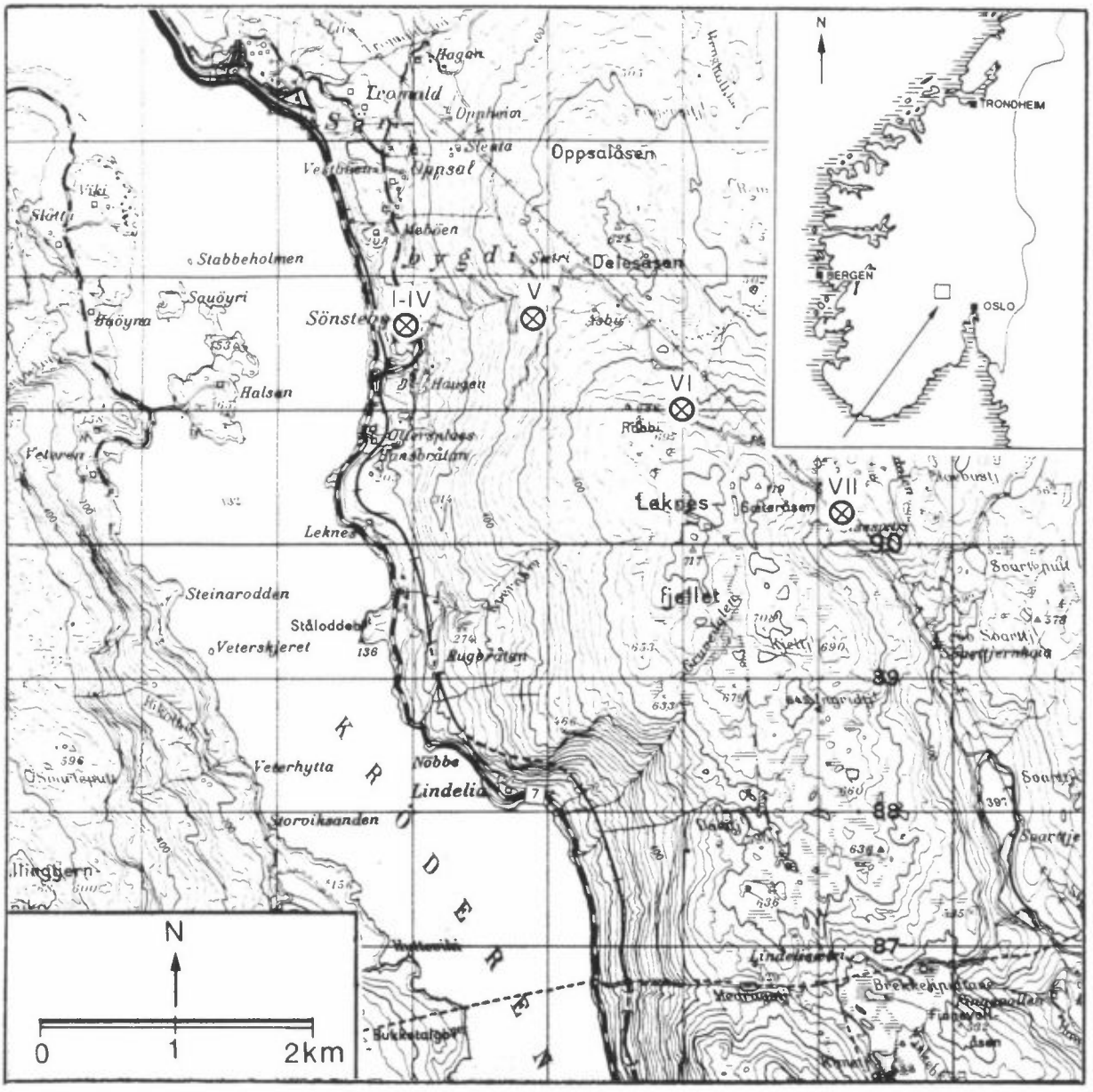

Figure 2: Location of the sampling sites.

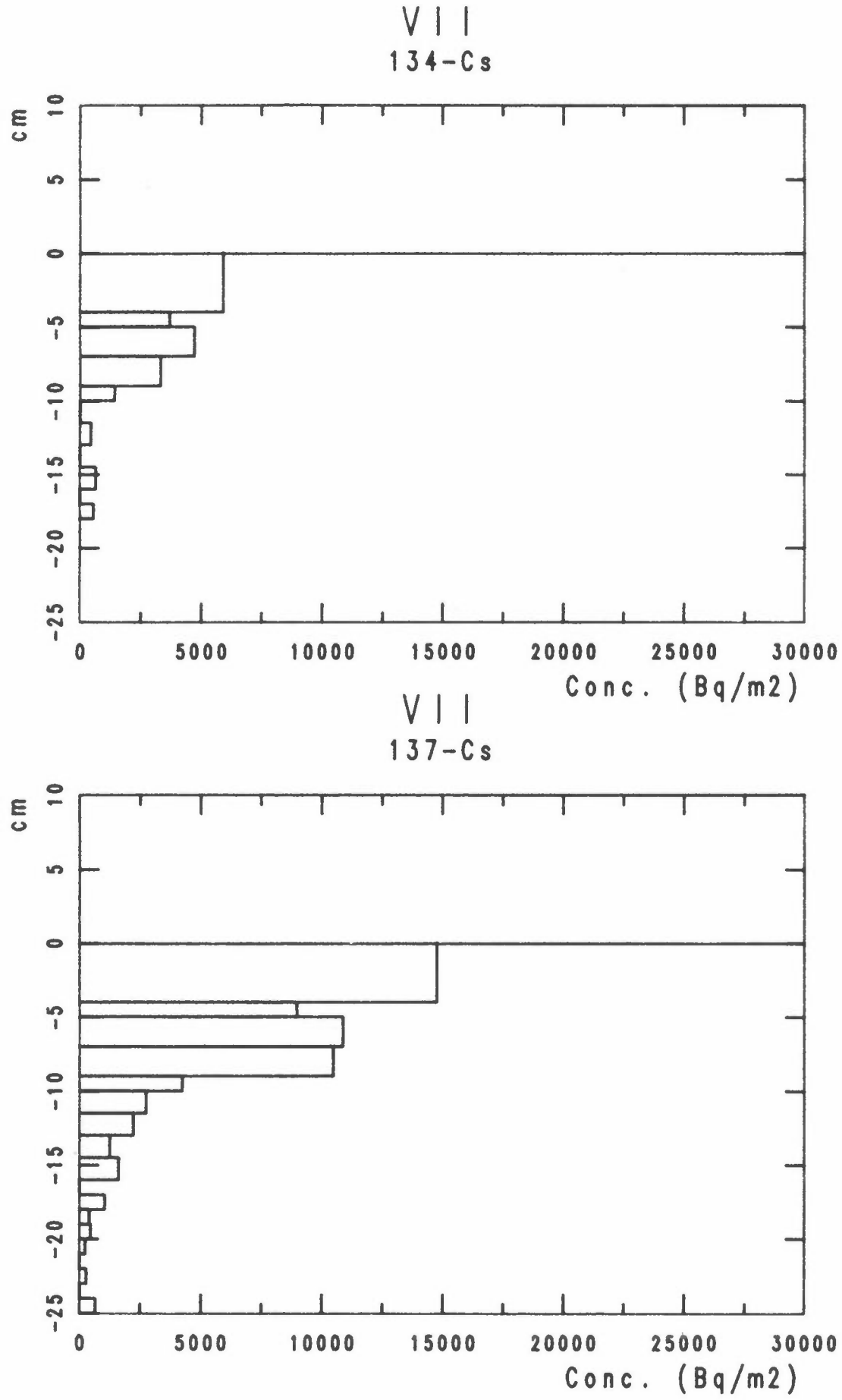

Figure 3: Concentrations of ^{134}Cs and ^{137}Cs in a peat bog samples collected at Gulsvik.

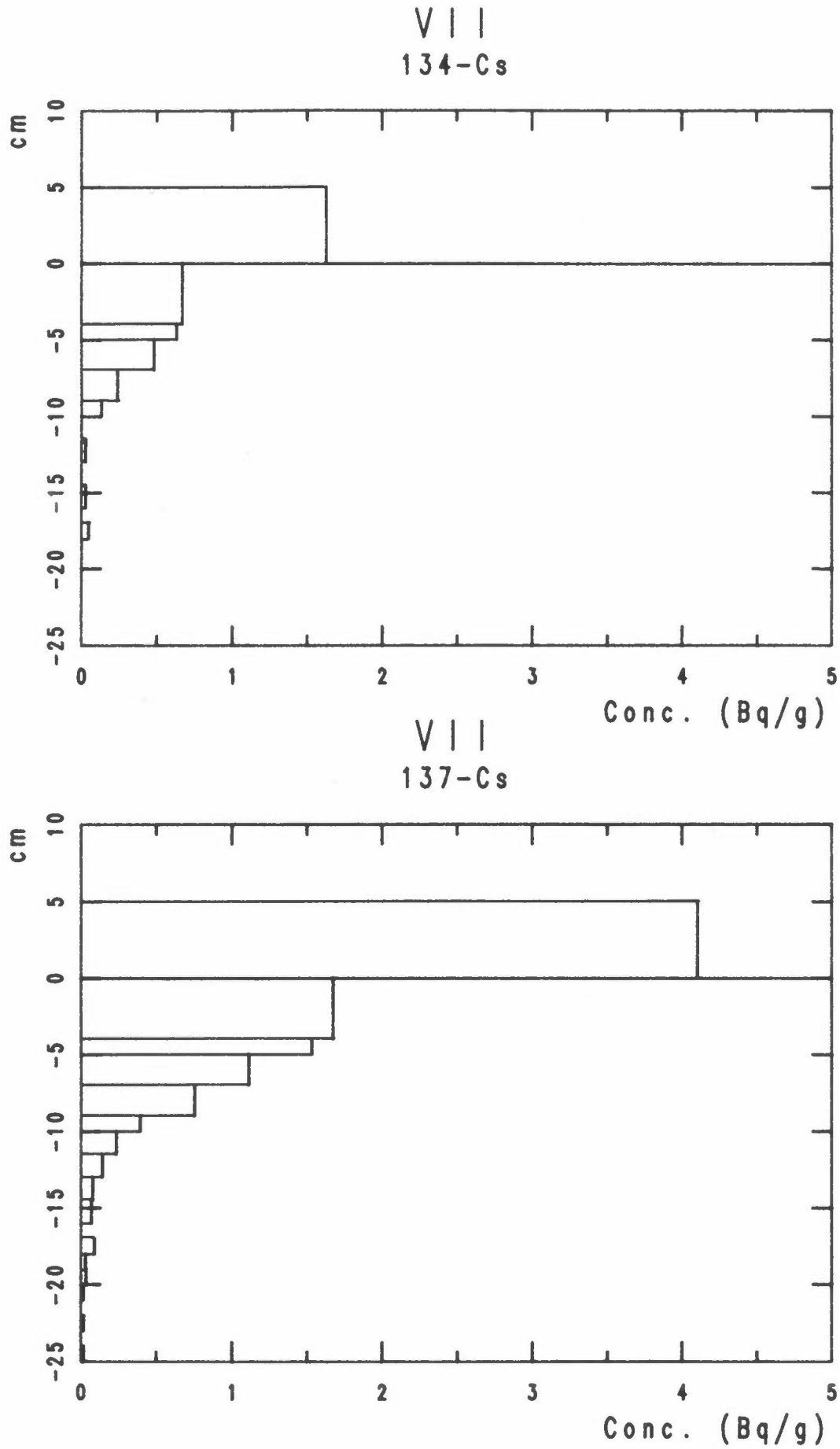

Figure 3 cont.

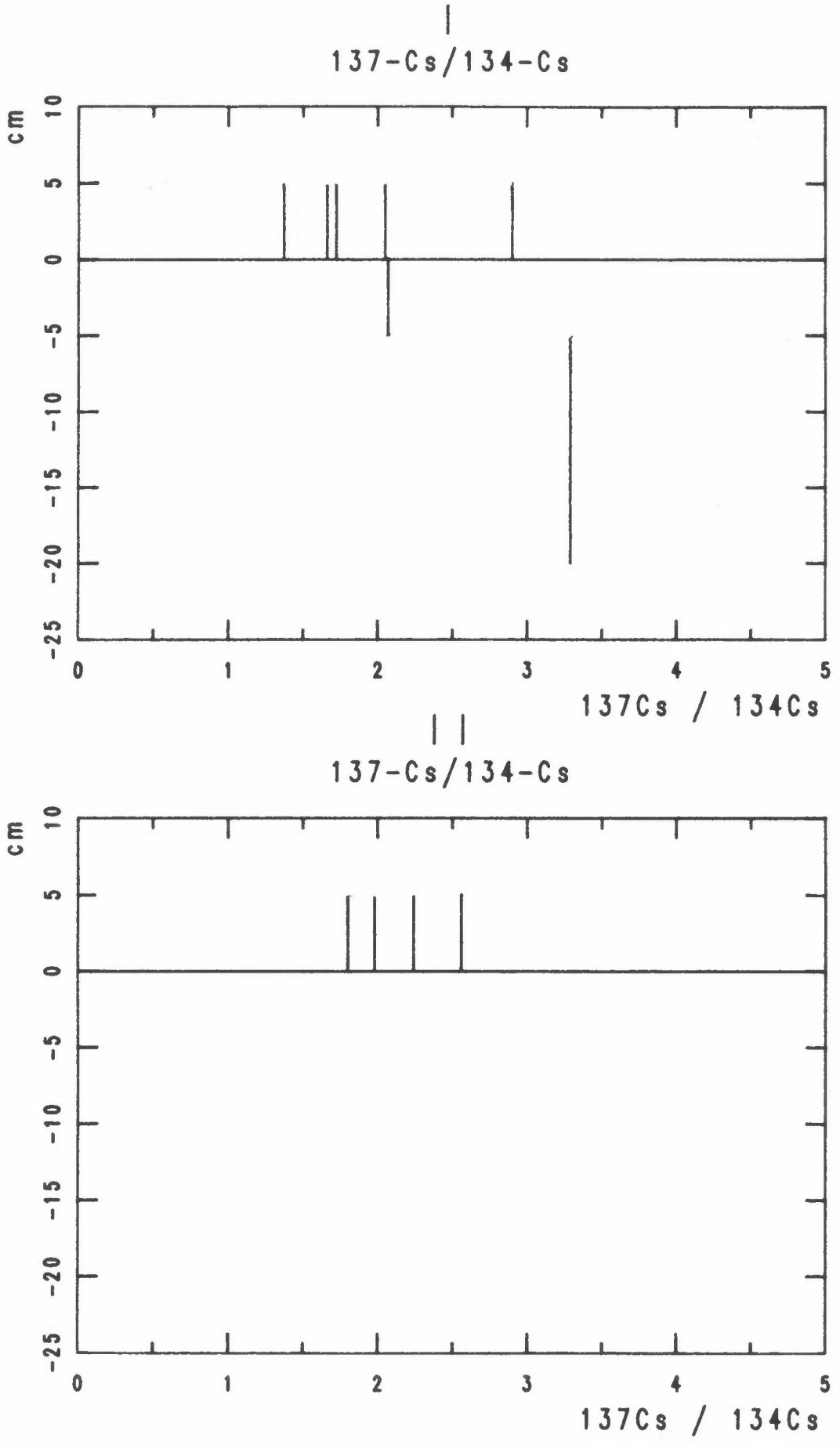

Figure 4: Ratio of $^{137}Cs/^{134}Cs$ for all samples.

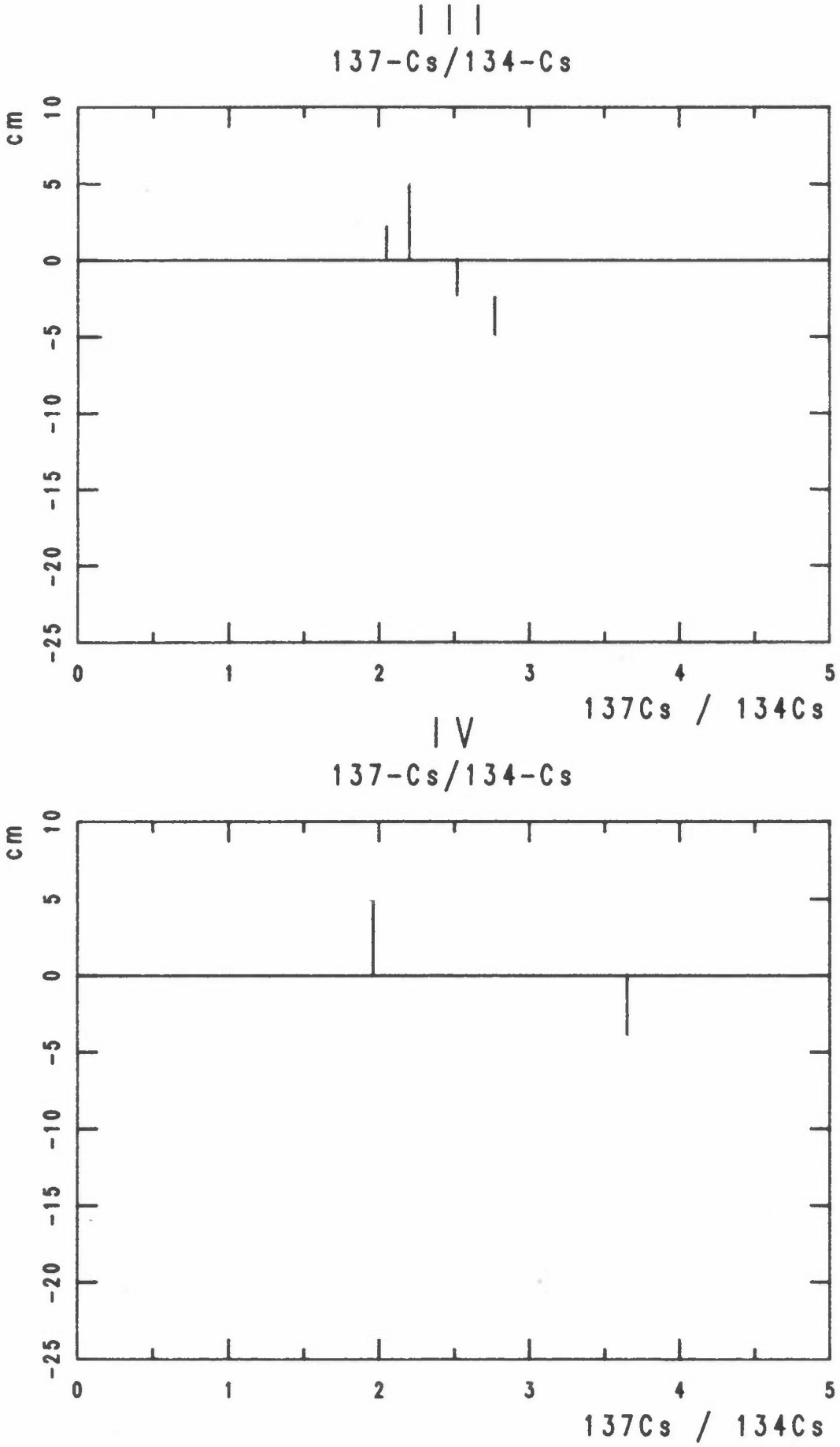

Figure 4 cont.

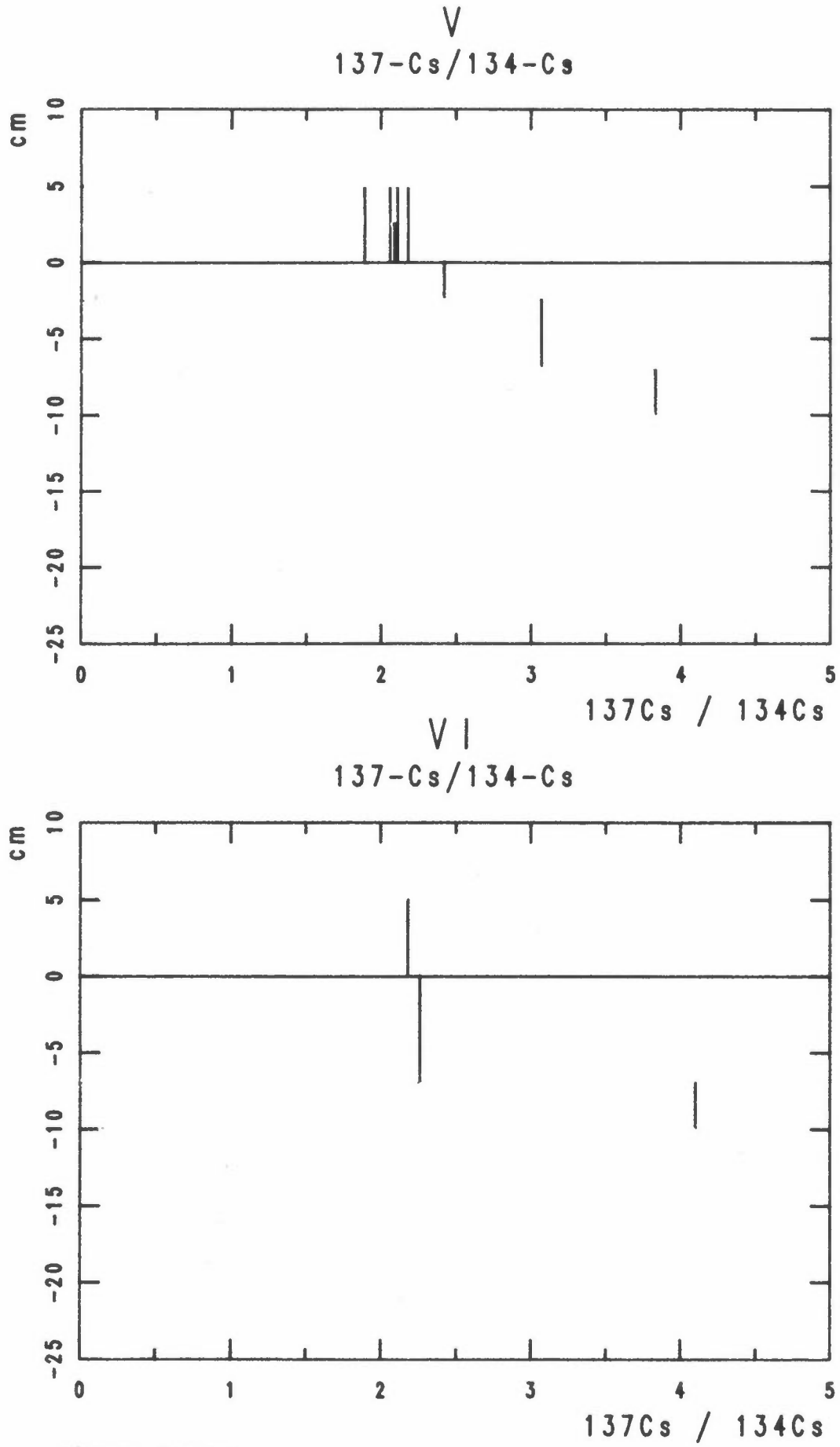

Figure 4 cont.

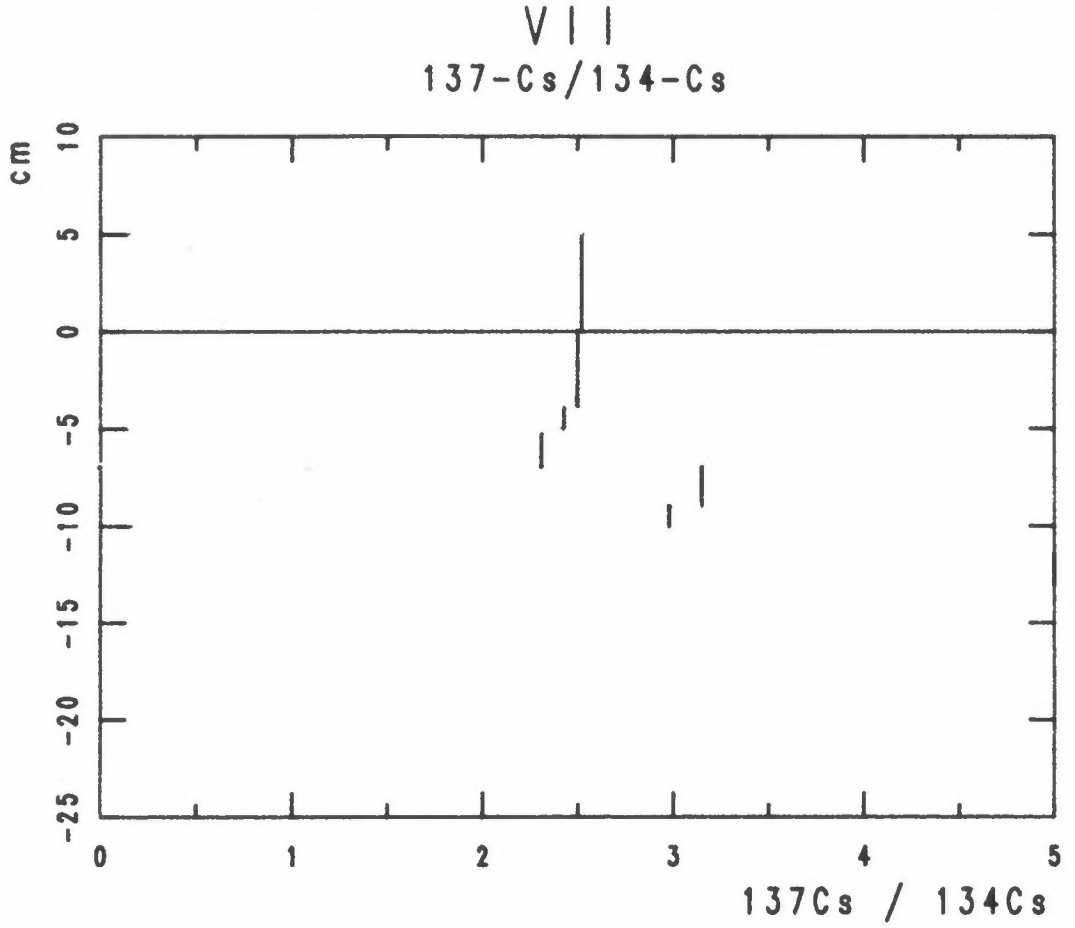

Figure 4 cont.

NORSK INSTITUTT FOR LUFTFORSKNING (NILU)
NORWEGIAN INSTITUTE FOR AIR RESEARCH
POSTBOKS 64, N-2001 LILLESTRØM

RAPPORTTYPE	RAPPORTNR.	ISBN
OPPDRAGSRAPPORT	TR 2/88	ISBN-82-7247-898-6

DATO	ANSV. SIGN.	ANT. SIDER	PRIS
FEBRUARY 1988	J. Schjoldager	26	

TITTEL
Migration of ^{137}Cs from air to soil and plants in the Gulsvik area, Norway after the Chernobyl reactor accident.

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OPPDRAGSGIVERS REF.

OPPDRAGSGIVER (NAVN OG ADRESSE)
NILU

3 STIKKORD (à maks. 20 anslag)
Radionuclide | Migration | Food chain

REFERAT (maks. 300 anslag, 7 linjer)

TITLE

ABSTRACT (max. 300 characters, 7 lines) A migration of ^{137}Cs from air to soil and vegetation after the Chernobyl accident is studied using the concentrations measured in the Gulsvik area in Norway. The major part of the ^{137}Cs from soil to plants through their root system is not a rapid process. Only a few per cent of the deposition can be traced in plants. This seems to suggest that as far as ^{137}Cs is concerned, an effect of the Chernobyl releases is not an acute but a long-term phenomenon. The ^{137}Cs accumulation in soils is rather high but does not result in ^{137}Cs levels in plants and diet higher than acceptable in Norway.

* Kategorier: Åpen - kan bestilles fra NILU A
Må bestilles gjennom oppdragsgiver B
Kan ikke utleveres C