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STUK-B-VALO 44

INTERIM REPORT ON FALLOUT SITUATION IN FINLAND FROM APRIL 26 TO MAY 4 1986

May 1986

FINNISH CENTRE FOR RADIATION AND NUCLEAR SAFETY

SURVEILLANCE DEPARTMENT

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PREFACE

As known, a reactor unit of type RBMK 1 000 ignited on April 26, 1986, approximately at 5 a.m. Finnish time*) in the reactor site in Chernobyl, some 130 kilometres from the city of Kiev in the USSR.

The Soviet authorities gave an official announcement saying that the reactor fire had ended on May 5 and the reaction had stopped.

This report presents results from external radiation measurements and analysis of environmental samples in Finland from April 26 to May 4, 1986.

Some additional calibrations will still be made, which will probably cause some changes to the results later. Also some checking of early warning monitors will most probably lead to some corrections in the results.

We believe, however, that the overall situation of radiation dose rate levels and the extent of environmental contamination is relatively well known for the purpose of protecting the public from external radiation and from radiation through the food chains.

The high fallout level will during this growing season cause several abnormal high contamination levels in different food stuffs. At this moment, at the beginning of May, the cows are still inside and the outdoor growing season is not yet fully started.

The elevated iodine-131 level in air outside and also inside of our laboratory has caused some problems in the gammaspectrometric iodine-131 measurements.

*) according to the official announcement given on May 6 the exact time was 1.23 a.m.

RADIATION MONITORING NETWORK IN FINLAND

The radiation monitoring network consists of ca. 270 radiation measurement stations kept by the Ministry of the Interior and the Finnish Defence Forces. The stations have been provided with Geiger-counters (Wallac RDA 31). During low radiation levels the measurement is based on the registration of pulses coming through the loudspeaker of the counter. Of the counters, 20 have been equipped with pulse meters (Wallac DPR 82), which makes the estimation of exposure rate possible on the basis of the results.

Normally the radiation measurement stations measure the radiation level every second day, the stations of the Ministry of the Interior and those of the Defence Forces on alternate days. The results are reported to the Finnish Centre for Radiation and Nuclear Safety through the Rescue Department of the Ministry of the Interior or through the NBC Defence Office of the General Headquarters.

The Finnish Meteorological Institute has a network of 10 stations for the measurement of aerosols. By means of this network it is possible to detect lower levels of radiation from artificial radionuclides than by using the counters of the first mentioned network. However, the stations were not in operation due to the state employees' strike.

When necessary, the Finnish Centre for Radiation and Nuclear Safety (STUK) sends out measurement patrols, which can be provided with complete equipment for measuring dose rates, as well as with portable Ge(Li) gammaspectrometers. Both nuclear power plants (Olkiluoto and Loviisa) have also been furnished with fairly complete measurement equipment.

ANALYSIS OF ENVIRONMENTAL SAMPLES BY STUK

STUK maintains continuous sampling as follows (the sampling in the environments of the Loviisa and Olkiluoto nuclear power plants takes place under the supervision of STUK and the samples are analysed in STUK.)

Air

A continuously operated station for sampling of air dust is situated in Nurmijärvi. One movable sample collector is at the moment operated in Konala, Helsinki. In addition, there are 4 collectors in the environment of Loviisa plant and 3 collectors in the environment of Olkiluoto plant.

Rain water

Collectors with a surface area of 1 m^2 are situated in Nurmijärvi and Lappeenranta and at the Loviisa and Olkiluoto plant sites. In the present exceptional situation, samples from the Nurmijärvi collector and from the temporary collector in Konala, Helsinki, are analysed daily. In addition, rain water stations provided with normal rain gauges are situated in Nurmijärvi, Jokioinen, Maarianhamina, Lappeenranta, Niinisalo, Tikkakoski, Savonlinna, Kuopio, Joensuu, Kauhava, Vaasa, Kajaani, Kuhmo, Taivalkoski, Rovaniemi, Sodankylä, Ivalo and Inari (plus 3 stations in Loviisa and 3 stations in Olkiluoto). At these stations, the rain water is normally collected monthly.

Surface waters

The radioactivity of river water is monitored by means of samples taken from the mouths of five rivers four times annually. The rivers are Tornionjoki, Kemijoki, Oulujoki, Kokemäenjoki and Kymijoki. The samples are analysed for gamma emitters and strontium. In addition, the tritium content is determined from the surface water samples taken from Lake Päijänne, Lake Inari and the Kemijoki. Samples from the drinking water of the towns of Loviisa and Rauma and of the Loviisa and Olkiluoto power plants are analysed four times a year.

Sea environment

Sea water samples are normally taken once a year from 9 stations in the Gulf of Finland, the Gulf of Bothnia and the Baltic Proper. Samples of the bottom sediment are taken from 5 stations. In addition, fish samples are taken from 4 stations along the Finnish coast. The sample species are herring and pike. At the moment, the research vessel Aranda is coming from the southern part of the Baltic and has some sea water samples with it. In the sea areas surrounding the Loviisa and Olkiluoto power plants, sea water samples are taken 4 times a year from 5 + 5 stations, samples of sedimenting matter are collected continuously from 4 + 3 stations, and fish samples twice a year from 2 + 2 areas. Four species of fish are analysed: herring, pike, perch and roach. Additional samples are taken from certain algae and from some bottom animals. The open water season in sampling has just started.

Foodstuffs

The radioactivity of milk is normally controlled with liquid milk samples taken once a week in Joensuu, Kursu, Pori and the Åland Islands. Dry milk samples are taken once a month in Scmero, Nastola, Lapinlahti, Seinäjoki, Haapavesi, Pori and Joensuu. Samples are taken every week up

to a distance of 10 km from the Loviisa and Olkiluoto power plants. Besides that, samples are taken in the whole production areas of the Loviisa and Rauma Dairies. In the present situation, the milk that is to be consumed is controlled daily south of the line from Kokkola to Iisalmi, including the Åland Islands. In addition, daily control samples are taken in Northern Finland.

Representative grain samples are taken from wheat and rye in the main production areas of these cereals each season. The control comprises 6 - 8 regional grain stores annually. Representative samples are also taken of wheat and rye in the surroundings of the Loviisa and Olkiluoto power plants up to a distance of 20 km every year.

The concentrations of radioactive substances in beef and pork are normally controlled in four areas from Southern Finland up to Oulu province in the north. Samples representing the production are taken twice a year: at the beginning and end of the grazing season. Samples of beef are taken in the surroundings of the Loviisa and Olkiluoto power plants up to a distance of 40 km twice a year. In addition, grazing grass is analysed in both areas twice a year.

The radioactivity levels of vegetables and fruits are normally controlled by means of representative composite samples taken from the products of several farms each season. Besides potatoes, also root crops, vegetables, berries and fruits are controlled. The outdoor products are followed extensively starting from the first early vegetables of the following growing season. Samples of lettuce are taken in the surroundings of Loviisa plant twice a year and a sample of apples once a year. Also in the surroundings of Olkiluoto plant, a sample of lettuce is taken twice a year and a sample of black currants once a year.

The control of radioactivity in foodstuffs will be continued and intensified in the coming growing season.

Following the activity level of the population

The amounts of radioactive substances in humans are followed with whole-body counter measurements. To control the activity level of the population, control groups, chosen among the inhabitants of the Helsinki, Loviisa and Olkiluoto regions, are measured annually. The activity measurements of the Lapps are continued in cooperation with the Institute of Radiochemistry of Helsinki University.

On the basis of the results of these measurements, an estimate is made of the so-called internal radiation dose caused by the radioactive substances inside the body.

Measurement equipment

For the analysis of environmental samples, the Surveillance Department of the Finnish Centre for Radiation and Nuclear Safety has

- 6 gammaspectrometers with high volume Ge(Li) or HP Ge detectors
- 8 low-background beta-counters, of which 2 have room for 10 samples
- 4 liquid scintillation counters
- alpha-spectrometric measurement capacity for 14 samples
- 4 zinc sulphide scintillation counters

For the measurement of humans, there are available 2 whole-body counters provided with semiconductor and NaJ(Tl) detectors, of which one is situated in a special measurement vehicle.

A METEOROLOGICAL SURVEY

Availability of meteorological data

Due to the state employees' strike, the Finnish Meteorological Institute operated only partially during the accident in Chernobyl nuclear plant. After the first symptoms of elevated radioactivity in Finland, the extent of operation was rapidly increasing and in 24 hours all essential weather stations were in full operation and the central computing unit was up again.

This report is essentially based on the normal weather information available in the institute. The only exception is that the trajectories with starting times on April 27th and 28th are calculated by the Swedish Meteorological and Hydrological Institute.

The report gives a qualitative description of the transport of nuclear emissions and of the effect of weather phenomena on the emission plumes. More detailed analysis of the event must be left to the future weeks.

The weather in Europe during the period

The weather in Europe in the morning of April 26th was dominated by a strong high pressure area over the Western parts of the Soviet Union and a low

pressure area that reached from Iceland to North-Western Europe. During the day a separate low pressure center was formed in Scandinavia. It moved quickly to the Norwegian sea and this move made room for a very warm air mass that streamed from the south to Finland. This warm air extended almost over the whole country before the morning hours of April 27th.

In the Chernobyl area (51°17'N, 30°15'E) the weather was at the starting time of the accident typical of a high pressure situation; winds were very weak and their direction varied strongly, a vast area of fog developed in the night. Higher in the atmosphere the wind field was more clear cut than on the surface. Already at the height of 1.5 km (850 mb level) the wind speeds were 8 - 10 m/s and they were blowing from the south-east or south. A clear wind canal that reached over the outmost western parts of the Soviet Union directly to Finland is shown in Figure 1. It is a 850 mb level weather map for the situation at 03 Finnish time (00 GMT) on April 26th, 1986. The stream velocities varied between 30 and 60 km/h, which means that the emission plumes moved easily in good 24 hours from the accident area to Finland. This can be seen in Figures 3 and 4, later in the text.

Later during this day a low pressure center from the Norwegian sea moved towards the east over Northern Finland. A relatively cold air that streamed behind the low center lowered the daily maximum temperatures in Northern and Western Finland. In the south-western and southern parts the air mass was still very warm.

During April 28th a high pressure ridge stretched from the Arctic Ocean to the Finnish Lapland. It brought a cold north-eastern flow that caused weak rain showers in the south. At the same time a uniform rain area developed in Mid-Sweden. The same rain moved during April 29th over Central and Southern Finland and disappeared in the early hours of April 30th to the south-east.

During May 1st, a high pressure center was formed in Western Europe and it made the winds in Scandinavia veer from the north-east to the north-west. The air masses in Finland were, however, continuously of an arctic origin. In the period from April 29th to May 4th no such air that had earlier been over the accident area streamed, not at least directly, to Finland.

The emission plume causes radioactive radiation on the surface by three different ways:

1) The radioactive gases that are transported in the atmosphere are inhaled by people and animals or the gases are adsorbed by plants.

2) Radioactive particles deposit as dry deposition on the ground.

3) Rain washes down both particles and gases.

The most effective way of cleaning the atmosphere is of course the rain that brings strong radiation doses to the ground. The radioactive fallout can cause a long-term increase in the intensity of the radiation measured near the ground.

Due to its central role, the rain information is compiled in Table 1. It gives the rain amounts in certain weather stations in Finland (see also the map in Figure 2) during the time period from April 26th to May 2nd.

The Table shows that rain occurred during the whole period in different parts of the country. On Sunday, April 27th, rain was located more in the eastern areas whereas on Monday most rains fell in the western areas.

On Tuesday, April 29th, the rain area coming from the west moved over the central and southern parts of Finland. The Table together with Figure 2 shows the areas with the highest rain amounts. During the following days Finland got more rains, but according to the previous weather reviews, additional radioactivity should not have fallen to the ground with these rains.

Trajectories as a tool in the description of the long-range transport

In this report the long-range transport to Finland (1 000 - 2 000 km) of waste substances emitted to the atmosphere is treated by using trajectories. The trajectory, calculated from actual weather data, gives an estimated transport route of the central axis of an emission plume. During the transport the plume spreads both in the vertical as well as in the horizontal directions.

Table 1. The rain amounts measured (mm) at given Finnish weather stations during the time period April 26th to May 2nd. Rain is measured between 09 hr (local) on a given day and 09 hr on the following day.

	26.4.	27.4.	28.4.	29.4.	30.4.	1.5.	2.5.
Kittilä Pulju	2.4	0.8	-	-	-	-	-
Sodankylä Lisma-Aapa	0.6	0.2	0.0	-	-	0.6	0.3
Oulu Linnanmaa	0.3	-	-	-	-	2.6	-
Haapavesi	-	-	-	0.7	-	-	1.2
Halsua	-	0.5	0.2	0.8	2.5	0.1	-
Honkilahti	-	-	-	1.7	1.6	-	-
Kuuskajaskari	-	-	1.1	4.6	-	-	-
Pälkäne Mykäälä	-	-	-	2.9	3.2	-	-
Hattula Leteensuo	-	-	0.2	6.7	3.0	-	-
Puumala	-	-	-	-	0.4	0.2	0.7
Outokumpu	-	-	-	0.0	0.3	-	-
Kuopio Inkilänmäki	-	0.0	-	1.2	0.2	3.5	0.1
Vesanto	0.5	0.7	-	2.7	1.9	0.5	-
Karttula	0.0	0.1	0.0	3.0	0.4	1.9	0.0
Kitee	-	-	-	-	-	1.2	-
Ilomantsi	-	-	-	-	-	0.1	-
Vieremä	1.8	2.3	-	-	2.8	-	-
Mikkeli	-	-	-	0.0	0.1	0.0	0.2
Lapinjärvi	-	-	-	3.6	4.9	-	-
Anjalankoski	-	-	-	3.1	5.8	-	-
Tuusula Hyrylä	-	-	-	0.1	1.4	-	-

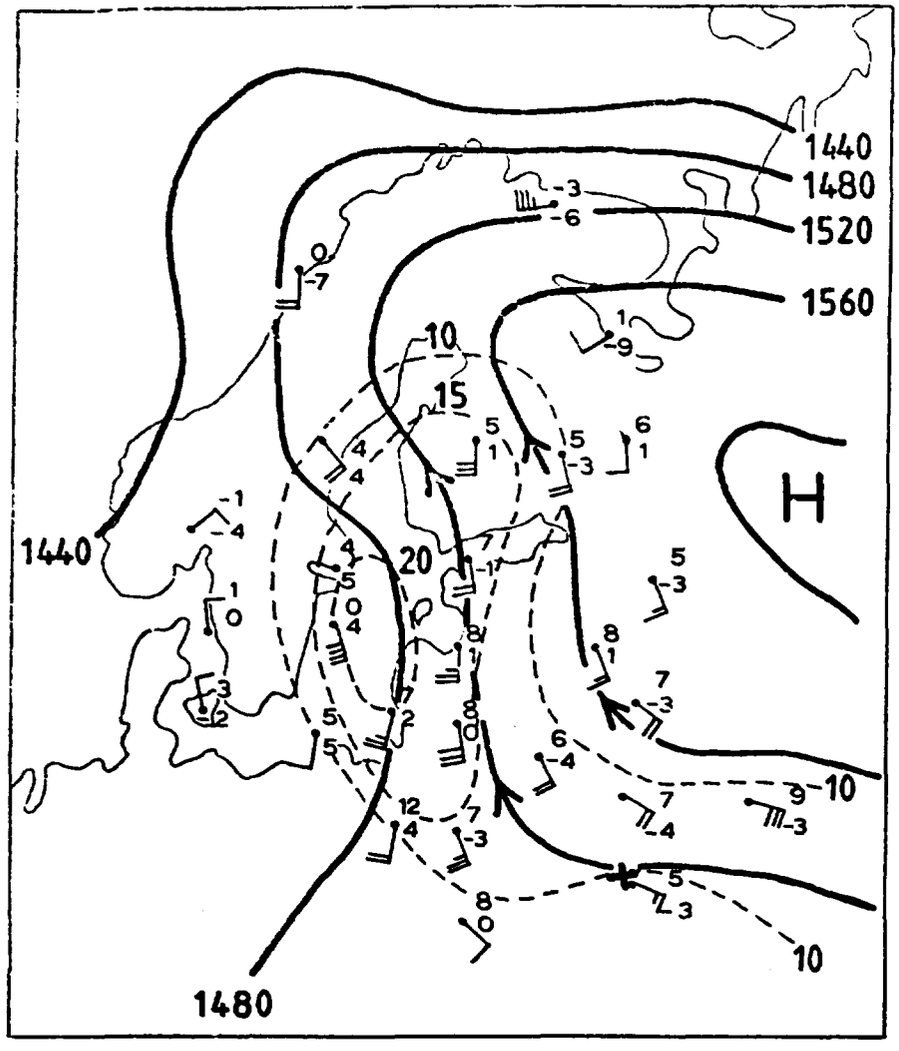

Figure 1.
850 mb level height analysis in the situation on April 26 at 03 Finnish time (00 GMT). The dashed line shows the analysis of wind speeds. The unit of speed is m/s.

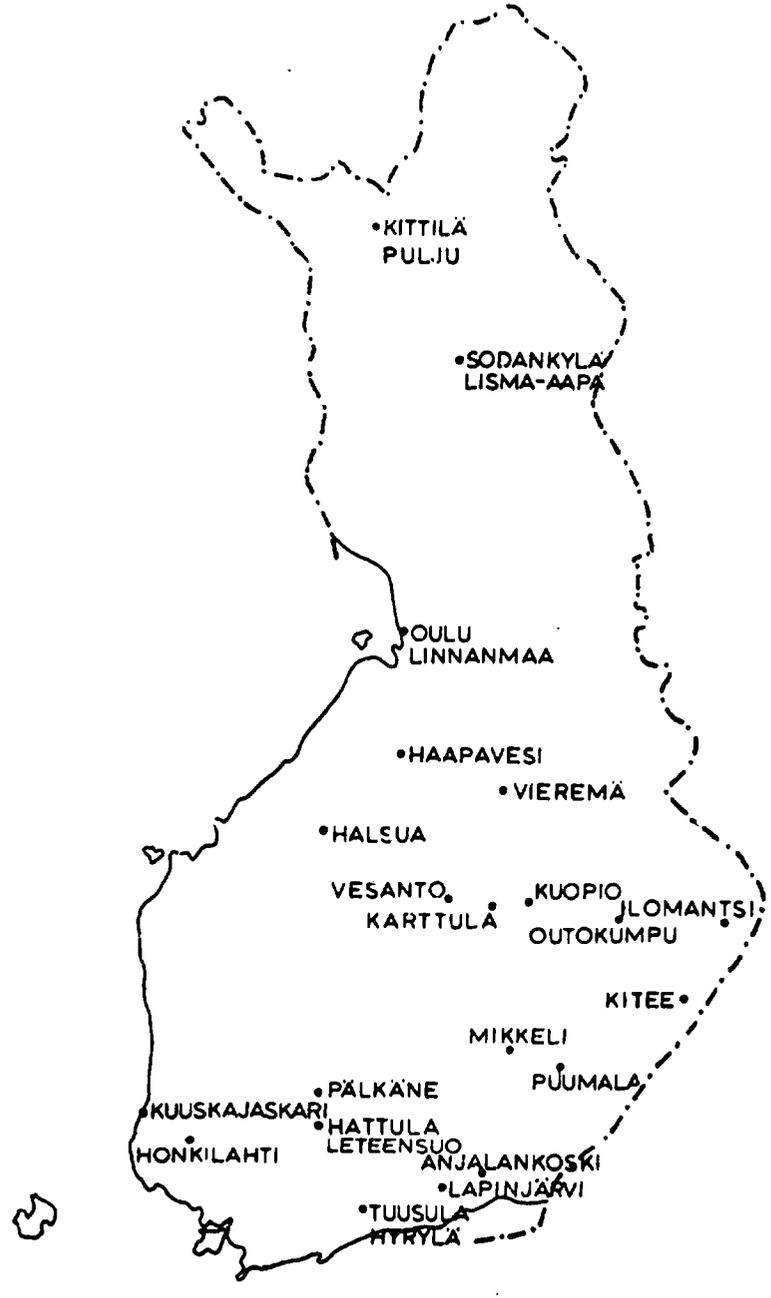

Figure 2.
Location of the weather stations in Table 1.

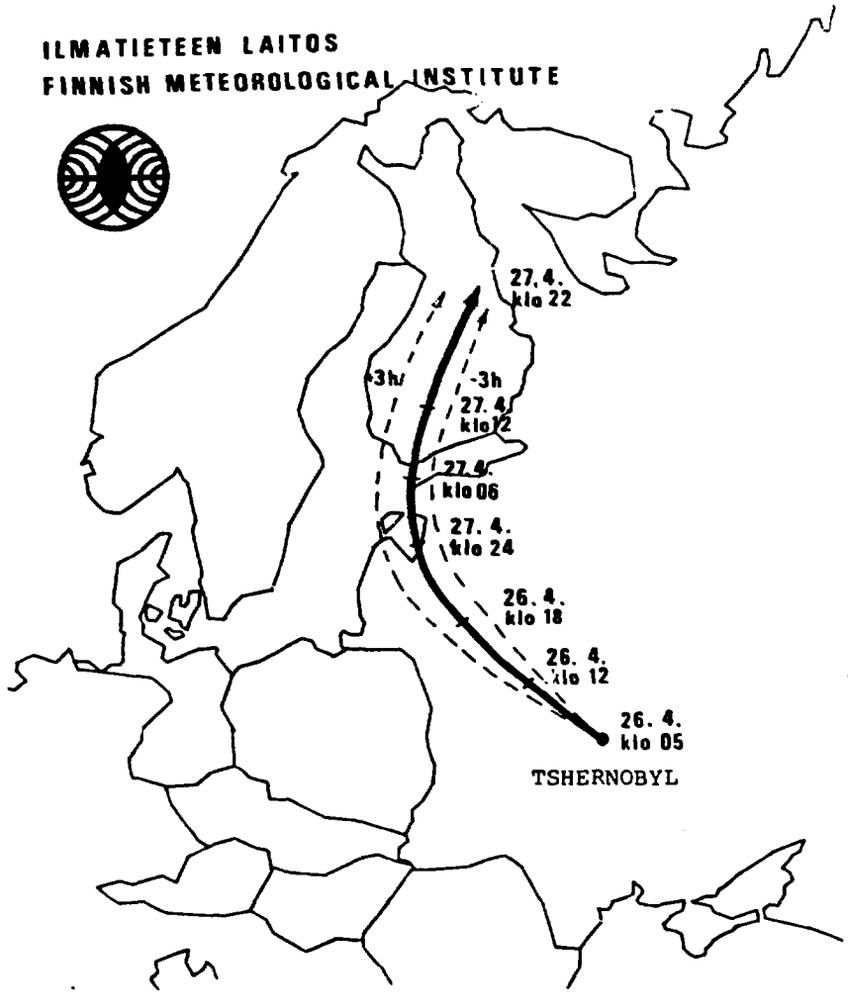

Figure 3.
The trajectory calculated from Chernobyl for the estimated time of accident on April 26 at 05 Finnish time (02 GMT). Trajectories with starting times 02 and 08 Finnish time (23 GMT and 05 GMT) are also included.

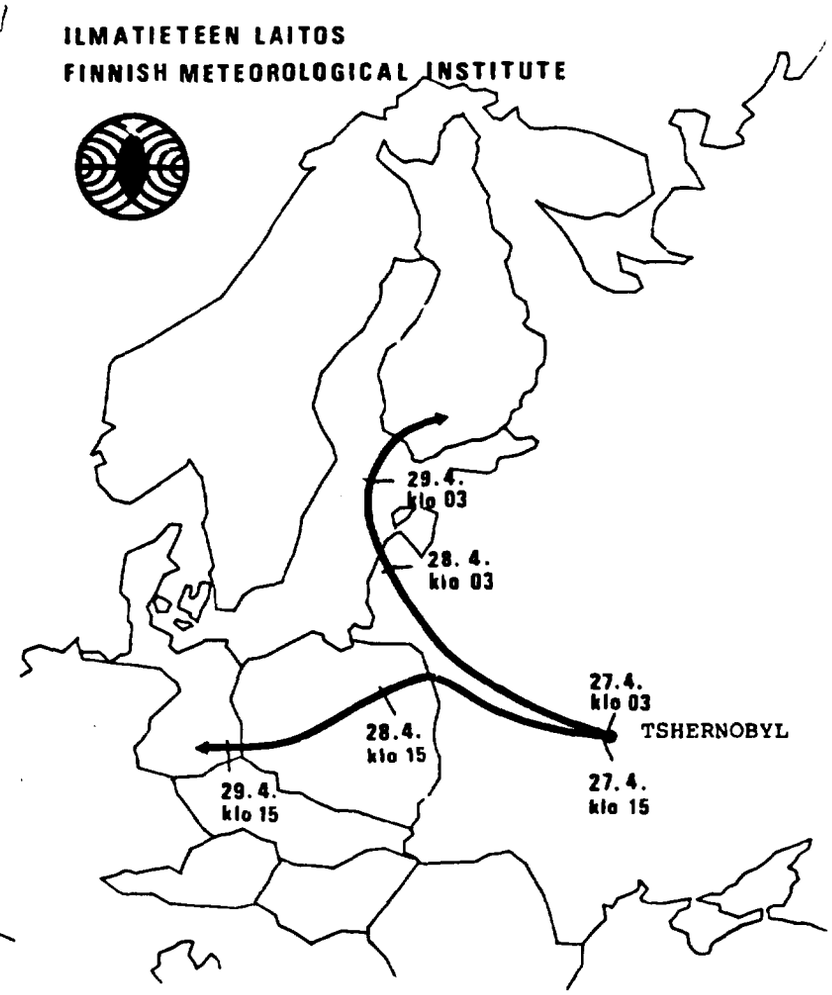

Figure 4.
Trajectories starting on April 27 at 03 and 15 Finnish time from Chernobyl.

The concentrations of emitted waste gases have their maximum at the central axis. A decrease of the concentrations at the height of the plume happens with increasing distances from the source. On the other hand the location of the maximum concentration observed at the ground level depends firstly on the height where the original emission happened and secondly, on the weather conditions along the transport route.

An emission plume that occurs at the height of a few hundred meters already has its maximum concentration at the ground level at a distance of one hundred kilometers.

In a fire of a nuclear reactor the amounts of heat energy released are extremely high. Due to that energy the emission plume can rise to a height from a couple of hundreds of meters up to a few kilometers. Besides on the released enery, the height is strongly dependent on the existing weather conditions.

On Saturday morning, 26th of April, the weather conditions (low winds, a wide area of nocturnal fog. etc.) give reason to expect that the thermal balance in the lower parts of the atmosphere has been very stable. In such conditions the warm exhaust air has risen as a tight plume to considerable heights. An estimated height of the emission plume at the accident place might have been between 500 and 2 000 m and the mean transport height approximately 1 500 m.

The transport of radioactive emissions

According to the trajectory which has as its starting time the estimated starting time of the major accident (Figure 3), the emission plume reached the Finnish south coast on Sunday before noon and the northern areas of Mid-Finland late in the evening. Because the exact starting point is unknown, Figure 3 also includes trajectories which have three hours earlier and three hours later starting times than the estimated accident time (05 $\pm$ 3 h Finnish time).

In the absence of accurate weather observations, radiosondings, etc., an estimation of the plume proportions when it arrived in Finland is a difficult task. It may have been so wide that it has covered the whole Finnish territory from west to east.

The vertical estimate is even more uncertain. However, when reaching the south coast the plume has not extended to the ground level. In its

way over the land the plume has flown to an active mixing layer, which brought parts of the activity down to the surface. The topography has obviosly had an effect on the plume.

In the northern parts of Mid-Finland the emission plume met a weather front that stopped further transport of the waste substances to Lapland.

During April 28th and the morning hours of the following day, the emission plume was still travelling towards the Finnish territory. At that time the route went also near the Swedish east coast (Figure 4). These air masses had their origin during the first hours of April 27th still over the accidetn place. In the afternoon April 27th the emissions were already heading towards the northwest or west.

The air masses that reached Finland during the period between Sunday (April 27th) and Tuesday morning (April 29th) stayed over the southern parts of the country. As the weather rewiev already pointed out, the arctic air masses that streamed from the northeast cleaned the atmosphere gradually. The clearning was strongly helped by the rain that preceded the cold front. On the other hand, the ground level values of the radioactivity had their maximum just in the rainy locations.

Figures 5 - 10 show that a direct transport was not experienced on the later occasions, but it can be said with a high probability that after the early morning hours of April 30th, the air masses did not bring with them additional radioactivity.

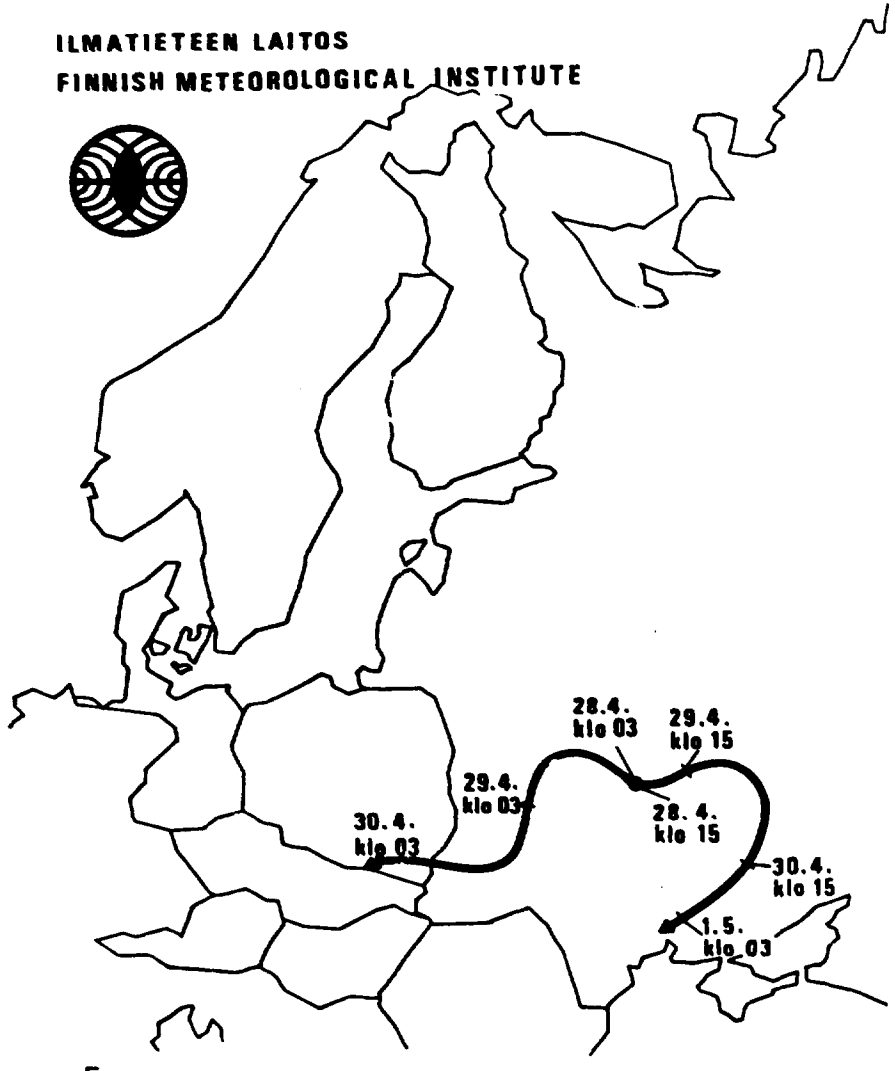

Figure 5.
Trajectories starting on April 28 at 03 and 15 Finnish time from Chernobyl.

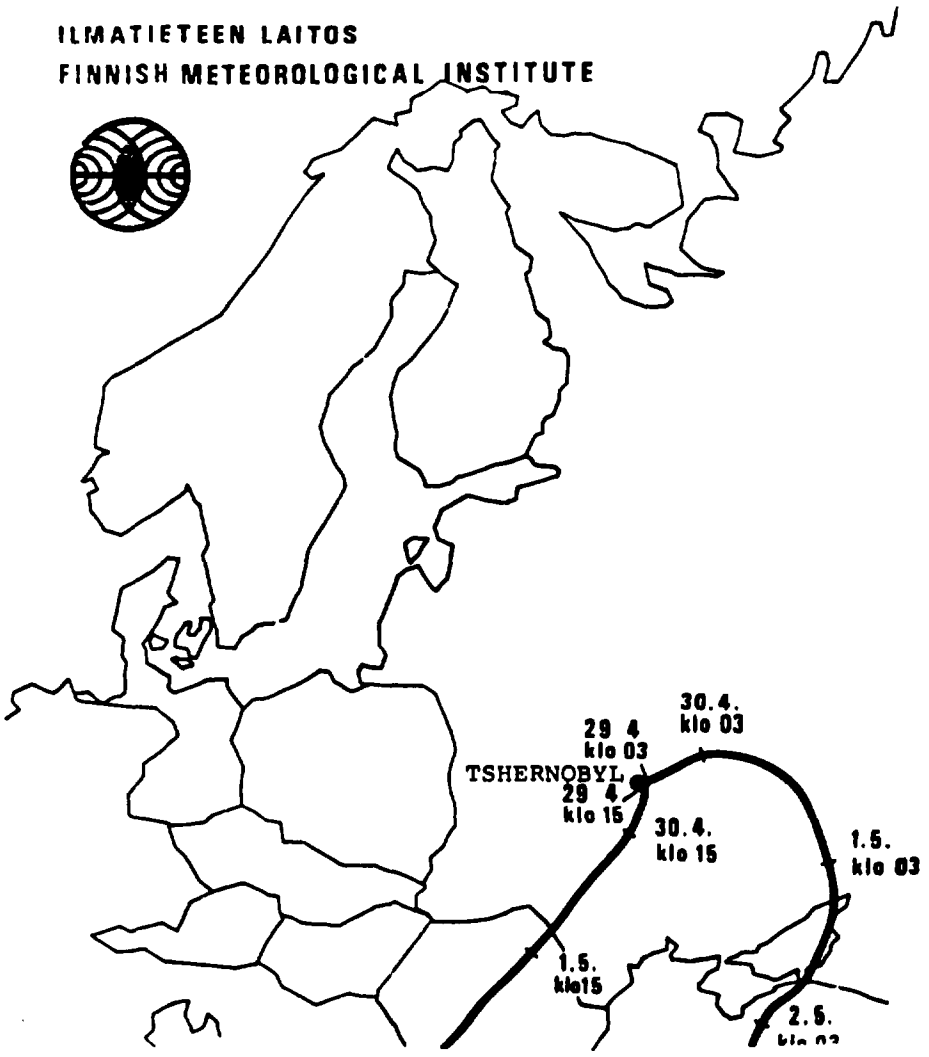

Figure 6.
Trajectories starting on April 29 at 03 and 15 Finnish time from Chernobyl.

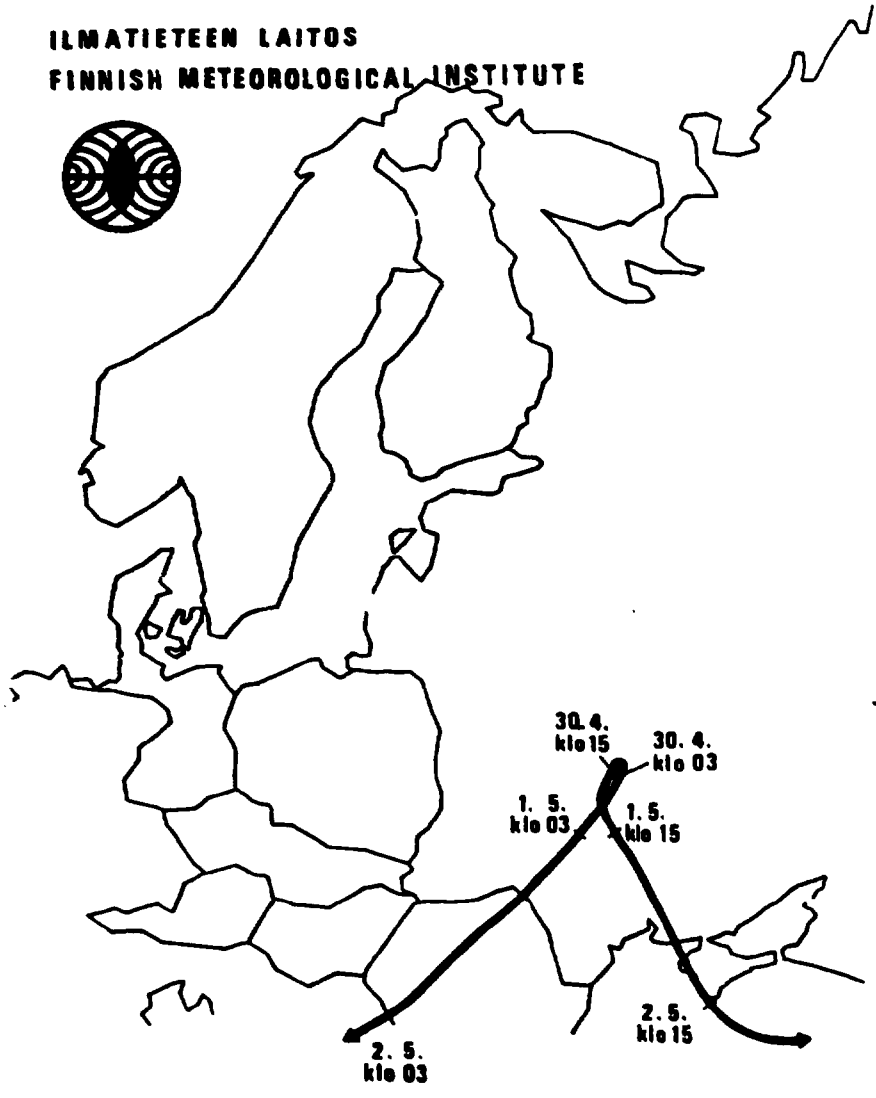

Figure 7.
Trajectories starting on April 30 at 03 and 15 Finnish time from Chernobyl.

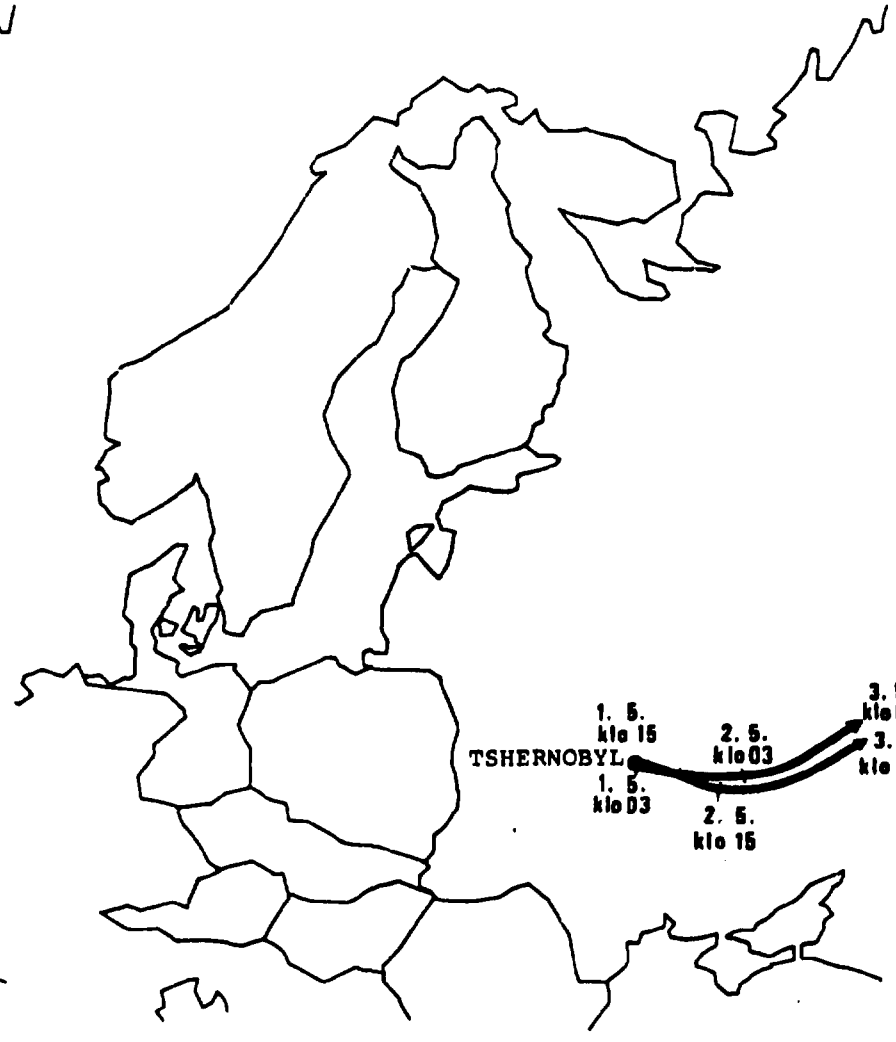

Figure 8.
Trajectories starting on May 1 at 03 and 15 Finnish time from Chernobyl.

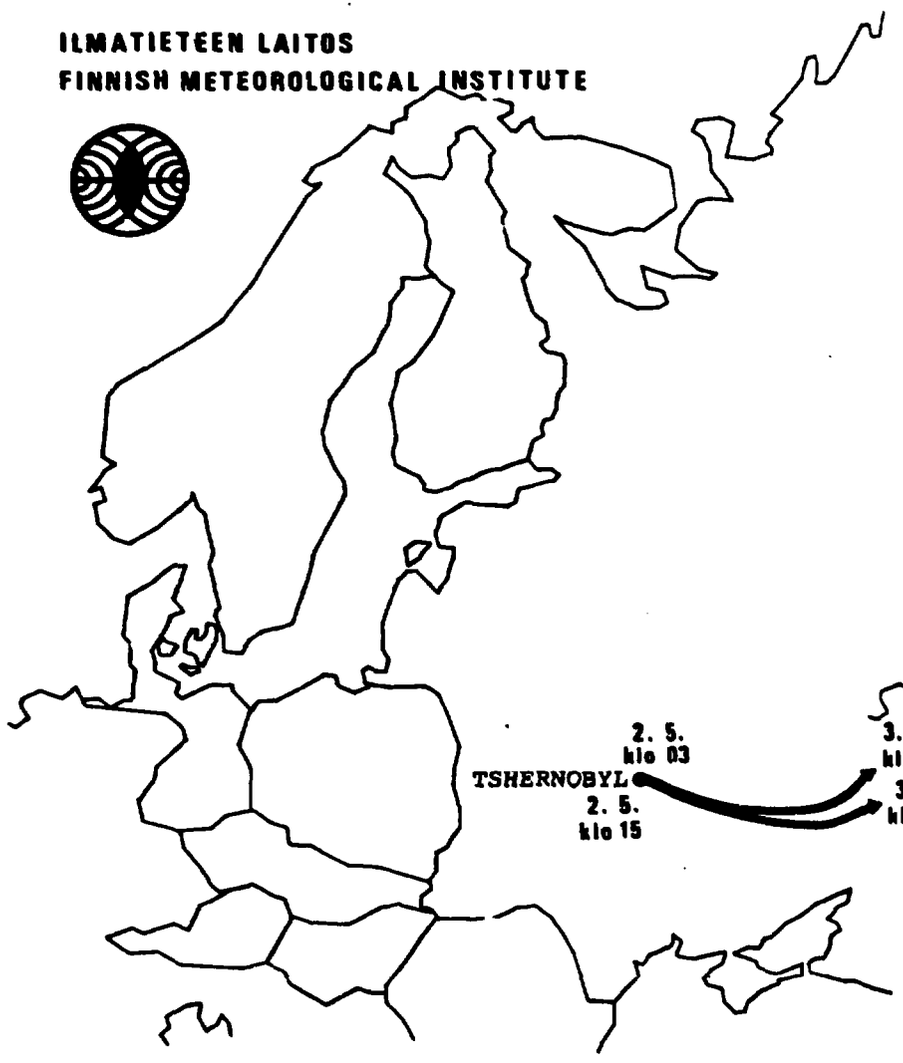

Figure 9.
Trajectories starting on May 2 at 03 and 15 Finnish time from Chernobyl.

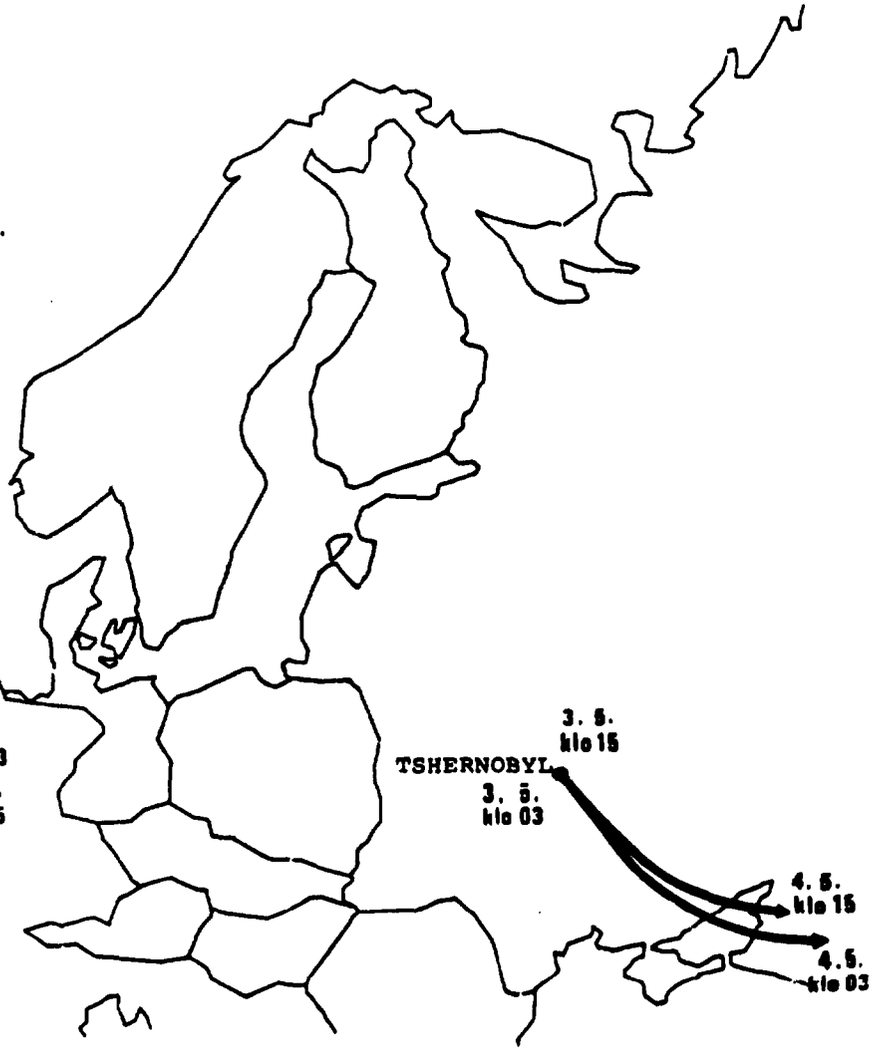

Figure 10.
Trajectories starting on May 3 at 03 and 15 Finnish time from Chernobyl.

DEVELOPMENT OF THE RADIATION SITUATION

The first observation of the coming fall-out was made in the radiation monitoring station of Kajaani. Dose rates of the magnitude 0.07 - 0.1 mR/h were measured there in the evening of 27 April 1986. The reason for the observation was discussed on Monday, 28 April. In Kajaani, there had been a heavy shower of rain, which had brought down a small amount of the fall-out.

It was considered that the radiation could have been caused by one of the radon peaks that have been detected in previous years as snow has melted in the spring. At the same time, the Rescue Department of the Ministry of the Interior asked for results from its own monitoring stations. At some stations there were results 1.2 - 2.5 higher than the normal values.

Monday afternoon it was heard that there had been a rise in the radiation level at Forsmark power plant in Sweden and that a spectrum containing several fission products had been measured there. Then it became clear that these observations were interconnected and that there was an exceptionally extensive fall-out situation at hand.

On Monday evening it was ordered that the radiation monitoring stations equipped with pulse meters measure the radioactivity at intervals of one hour. On Tuesday evening it was decided that measurements should be carried out in the radiation monitoring network of the whole country (ca. 300 stations) at 7.00, 15.00 and 23.00 hr.

On Tuesday, 29 April, a considerable rise in the local external radiation levels could be detected first in the western parts of the country. Similar observations were made also elsewhere in Southern and Central Finland later on the same day. The rises in radioactivity were related to a rain area, which brought the radioactive substances to ground from the height of about 1 to 1.5 kilometres.

The highest external exposure rate that was detected was 0.4 mR/h in Uusikaupunki on 30 April. Even higher figures have been reported but when controlled, they have shown to be momentary or uncertain. Table 2 shows the development of the daily situation in 13 stations operated by the Ministry of the Interior.

Thereafter the level of external radiation has been decreasing at most stations. The calculatory half-time is about six days. Figure 11 shows a

Table 2.

Exposure rates measured at radiation monitoring stations (uR/h)

Radiation monitoring station	Date							
	28.4.	29.4.	30.4.	1.5.	2.5.	3.5.	4.5.	Background
Kerava	11,8	3,3	16,2	17,8	17,1	13,7	12,4	9,2
Loviisa	-	0,5	49,0	42,7	35,3	32,1	29,1	14,2
Uusikaupunki	13,7	384,7	319,7	264,1	225,5	192,8	164,0	10,0
Vammala	21,8	80,8	84,4	64,0	55,4	53,5	45,5	11,3
Rauma	16,9	122,7	112,5	96,2	83,5	76,8	66,1	11,3
Forssa	10,1	28,8	32,2	29,2	26,6	(59,3)	18,5	9,2
Heinola	-	91,9	78,1	66,7	56,8	54,7	48,2	11,3
Pieksämäki	-	149,5	116,0	98,8	93,5	86,1	76,1	11,3
Seinäjoki	-	70,2	64,4	64,5	62,8	55,4	49,5	8,7
Kokkola	-	43,6	36,7	33,2	30,7	27,1	23,5	8,7
Ylivieska	-	7,6	4,3	6,7	5,2	4,8	4,8	9,4
Raahe	-	0,1	0,3	0,1	2,5	1,8	2,1	9,0
Kuusamo	-	0,2	0,3	0,3	0,3	0	0	9,0

The table includes the highest measured exposure rate on the days when the fall-out, or the preceding initial peak (at some stations), was detected for the first time. On other days the results were recorded at noon. The share of background radiation has been deducted.

computer-aided map of the situation on 4 May. The figure indicates the areas in which the exposure rate is more than 10-fold, more than 5-fold and more than 2-fold when compared with the normal values.

In the negotiations conducted on Wednesday morning, 30 April, it was agreed with the state employees on strike that work could be commenced at monitoring stations, at the Finnish Meteorological Institute and at the Finnish Centre for Radiation and Nuclear Safety.

External radiation, gammaspectrometric measurements

The radiation field was measured in four places in an open field by using semiconductor detectors. From the spectra it can be seen which radionuclides cause radiation, and calculations can be made concerning the share of the most important nuclides in the exposure rate and the activity per unit area in the ground. The results are shown in Table 3. At the same time, the total exposure rate given in the table was measured with an effective Geiger-tube. Knowing the share of each nuclide in the exposure rate is necessary for calculating the decrease rate of the radiation level and the radiation doses received. Figure 13 illustrates the spectrum obtained in Lieto.

Radiation measurement flights

The purpose of the aerial survey of radiation has been to map the radioactivity that exists at various heights in the air. During the flights, there have been direct gamma measurements and samples have been taken.

The flights have not been intended for measuring radiation levels on the ground. There have been flights daily since Monday, 28 April.

In the evening of 28 April, the radiation level was a little higher at 500 metres. The highest values were at the height of 1700 metres, the maximum being 10 times the normal background.

On 29 April, the radioactive cloud was in Southern Finland, to the west of the line from Kouvola to Porvoo, mainly at the height of 1 to 2 kilometres extending to the ground where there was rain. The concentration of iodine-131 at 1000 metres between Helsinki and Porvoo was 600 Bq/m^3.

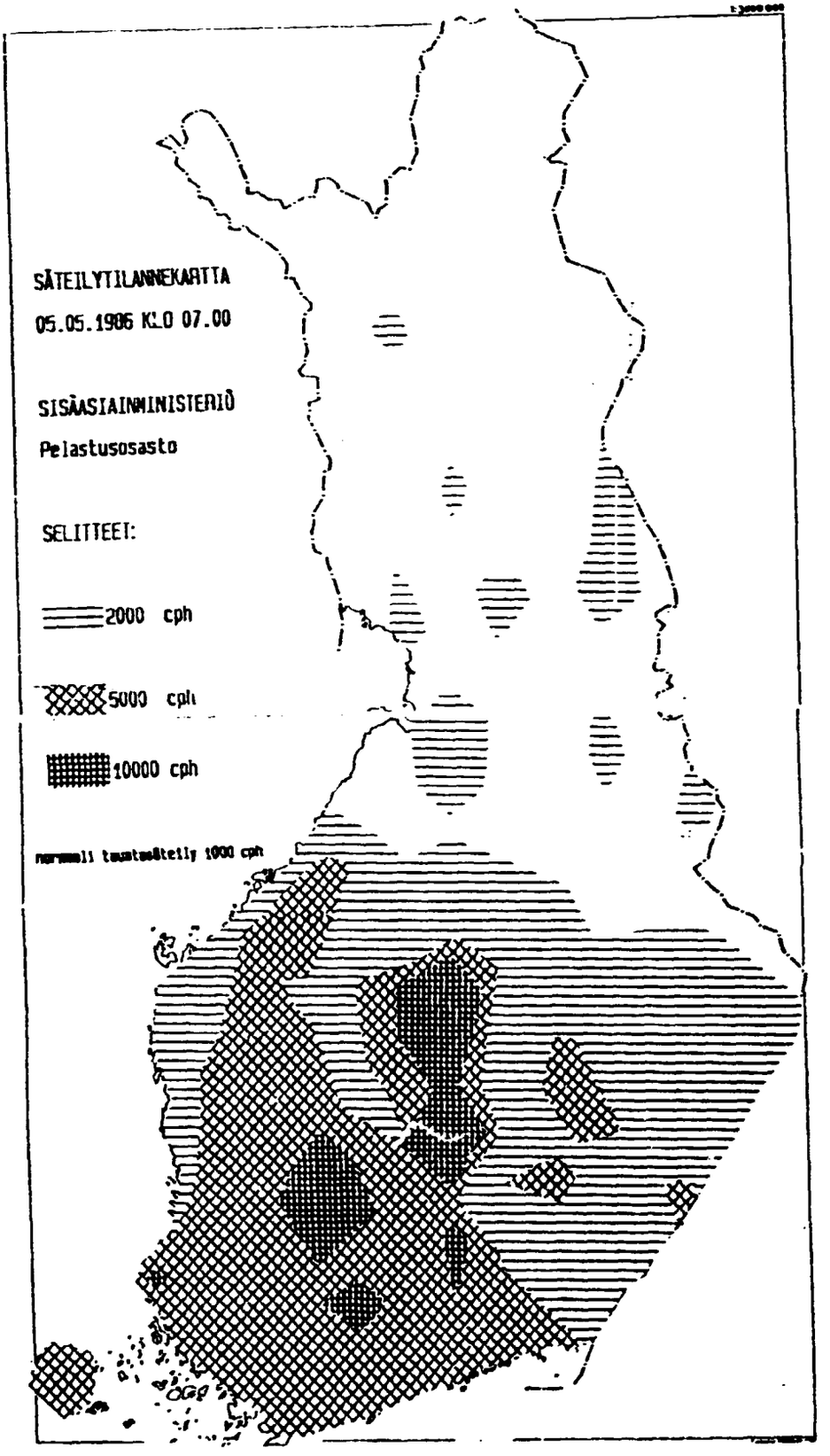

Figure 11.
Count frequencies detected with radiation monitors (impulse/hour)

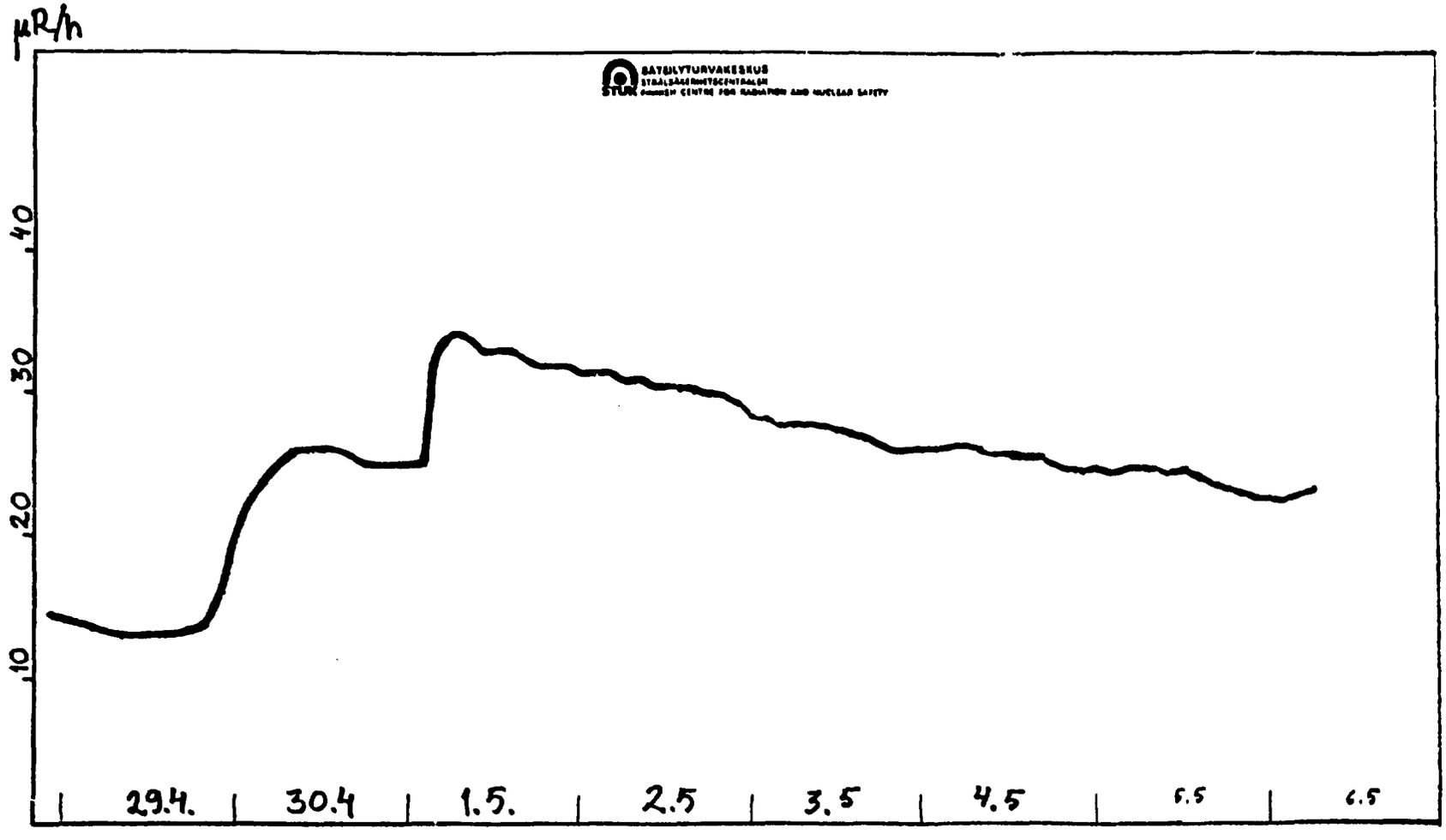

Figure 12.
Total exposure rate in Konala, Helsinki (µR/h)

Table 3.

Direct spectrometric measurements on 29 april 1986 performed in an open field at a height of 1 metre with a HP Ge-detector

Nuclide	Vihti Bq/m^2	D uR/h	Karkkila Bq/m^2	uR/h	Forssa Bq/m2	uR/h	Lieto Bq/m^2	uR/h	T 1/2
J-131	6 350	1,3	11 000	2,2	48 700	9,7	105 000	21	8,04 d
TE-132	390	0,04	580	0,06	49 100	5,1	113 000	12	78,2 h
J-132	250	0,3	370	0,42	39 800	4,5	98 300	112	(2,38 h)
Cs-137	390	0,11	350	0,10	465	1,3	8 880	2,6	30,2 y
La-140	260	0,3	380	0,5	4 070	5,4	5 670	7,5	12,8 d (Ba-140)
D Sum		2,1		3,3		67		155	
D Measured		12,5		12,2		64		145	
D Cs-137		0,05		0,03		0,02		0,017	
D Sum									

- Assumed level source

- The dose rate calculated from the spectrum D sum is in good agreement with the dose rate measured on the GM-tube (MC 70) (including natural background radiation), considering the accuracy of the measurements.

  In clay soil the dose rate of Cs-137 is halved as the distribution deepens

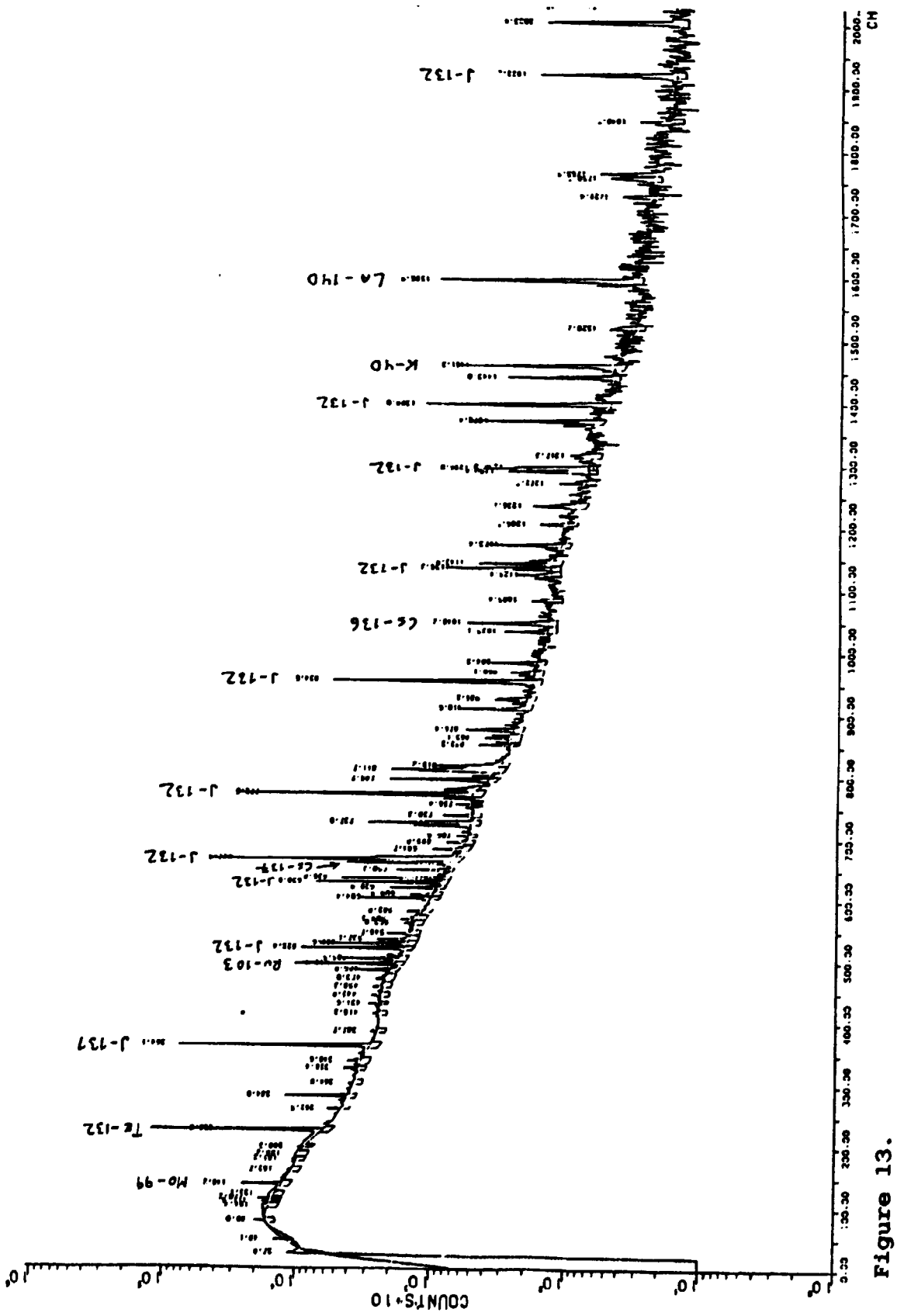

Figure 13.
Gamma spectrum of a radiation field measured with a semiconductor spectrometer in an open field. The measurement was made in Lieto on 29 April 1986 at 21.15 hr. The most important causes of the exposure rate are shown in the figure.

In the morning of 30 April, the radioactive cloud had disappeared from above Southern Finland. The concentrations of iodine-131 at 1 to 2 kilometres were of the same order of magnitude as the concentrations in the ground level air, i.e. 1 - 5 Bq/m^3. From 1 to 4 May there were no indications of air-borne radioactivity.

CONTROL OF RADIOACTIVITY IN MILK AND ENVIRONMENTAL SAMPLES

Air

Relative to the nationwide radiation monitoring of air, the Finnish Centre for Radiation and Nuclear Safety has a high-capacity collector of air dust in Nurmijärvi. After the air has passed a glass-fibre filter, a sample of it is taken into an active carbon cartridge. In accordance with the normal collection program, the filter of this air collector was replaced on Monday, 28 April at 09.35 hr. This filter had been in the collector since Thursday, 24 April, 09.35 hr. After Monday, the filters and active carbon cartridges have been replaced more frequently. On Monday, the collection of air samples was also begun with a smaller collector with a glass-fibre filter in the Surveillance Department of the Finnish Centre for Radiation and Nuclear Safety in Konala.

Table 4 shows the concentrations of various radionuclides in Nurmijärvi on Monday, 28 April between 15.00 and 21.00 hrs. At that time the concentrations reached their maximum in Nurmijärvi. Results from the active carbon cartridge behind the glass-fibre filter indicated that about 85 % of iodine isotopes had penetrated the filter. The iodine contents in Table 4 have been corrected with the results obtained from the active carbon cartridge.

Figures 14 and 15 show the development of the concentrations of iodine-131 and cesium-137 in the air of Nurmijärvi after Monday. The figures do not include results from 24 to 28 April because the exact starting time of the fall-out is not known.

Table 5 shows the development of the concentrations of ten radionuclides in the air of Konala starting from Monday. The concentrations of iodine isotopes have been corrected in this table, too, by assuming that 85 % of iodine-131 and iodine-133 have penetrated the glass-fibre filter.

Table 4. **Radionuclide concentrations in ground level air at Nurmijärvi 28th April from 3 pm to 9 pm. The sample was collected simultaneously on a glass-fibre filter and an activated charcoal cartridge. The results showed that about 85 % of iodine isotopes have penetrated the glass-fibre filter.**

Nuclide	Concentration in air mBq/m^3
Zr-95	350
Nb-95	450
Mo-99	2 450
Cd-115	770
Sb-127	1 200
Ru-106	2 400
Te-129 m	6 600
Te-131 m	1 120
Te-132	35 000
I-131	205 000
I-133	55 000
Cs-134	6 470
Cs-136	2 700
Cs-137	11 200
Ba-140	5 350
Ce-141	510
Ce-144	370
Np-239	3 270

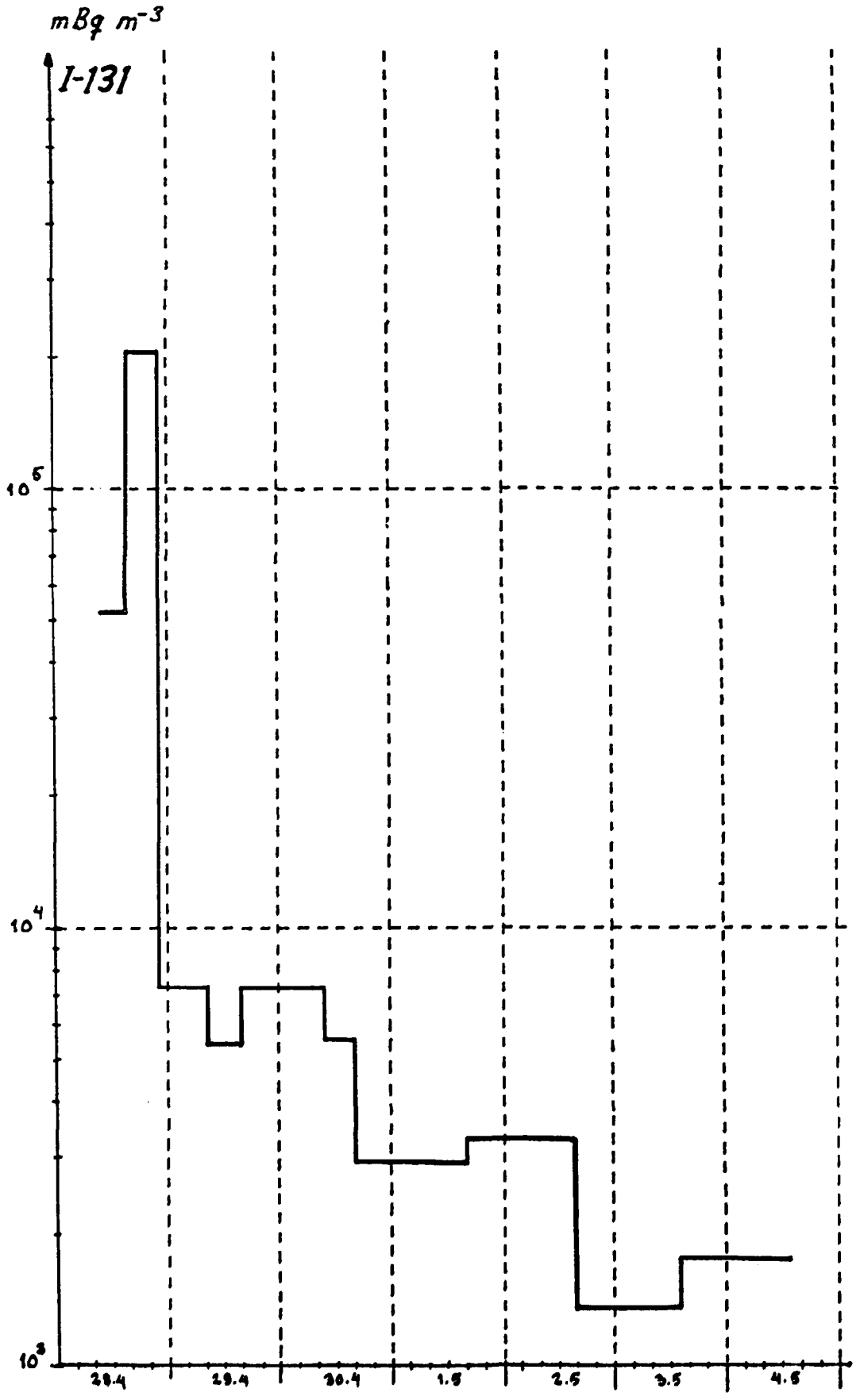

Figure 14.
Development of iodine-131 concentration in surface air in Nurmijärvi from 28 April to 4 May 1986.

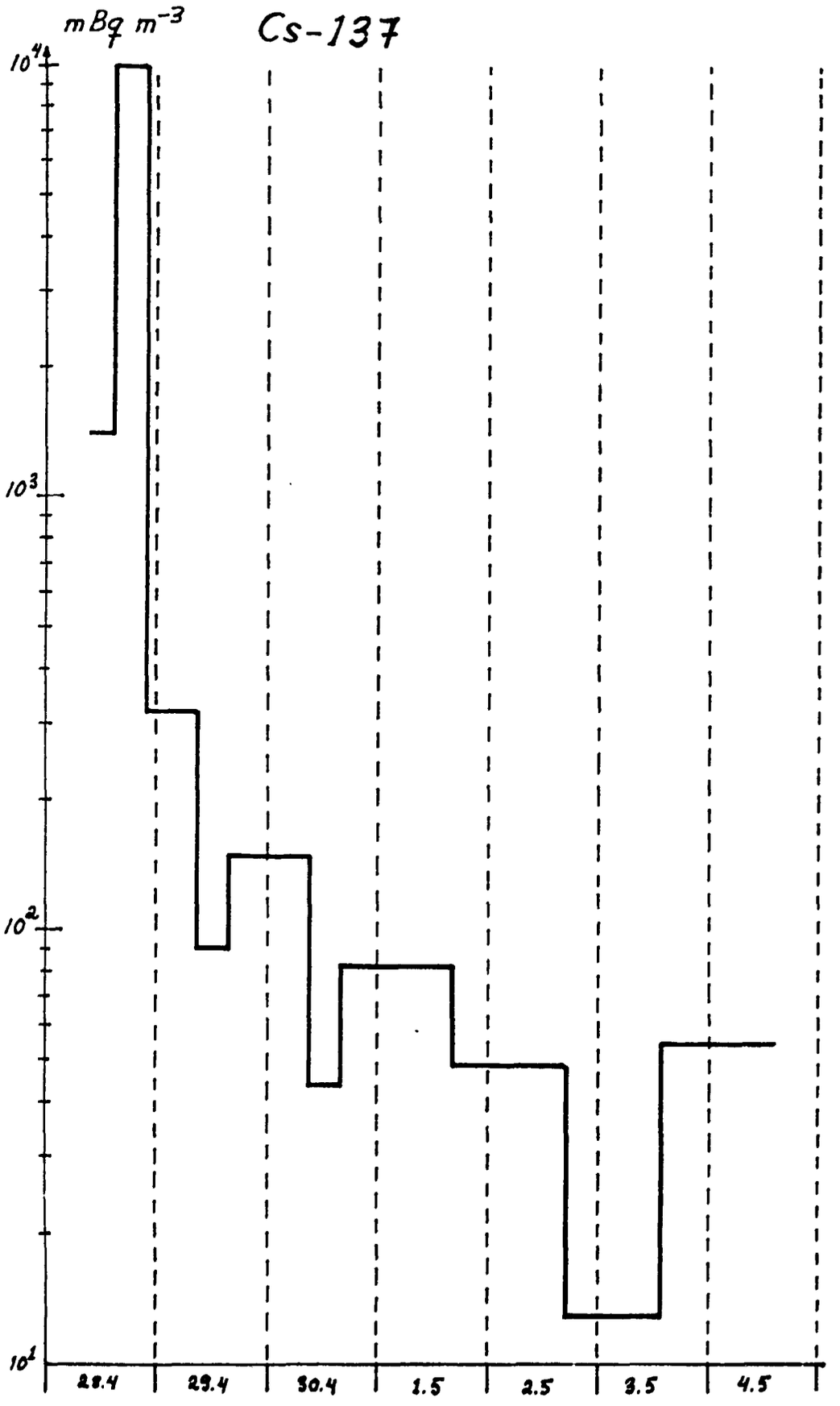

Figure 15.
Development of cesium-137 concentration in surface air in Nurmijärvi from 28 April to 4 May 1986.

Table 5.

Concentrations of various radionuclides in surface air in Konala, Helsinki from 28 April to 5 May 1986 ($mBqm^{-3}$)

From	To	Zr-95	Ru-103	I-131	Te-132	I-133	Ba-140	Cs-137	Cs-134	Cs-136	Np-239
28.4.86 17.30	28.4.86 18.50	185	512	108 700	5 560	24 600	1 310	2 725	1 635	687	970
28.4.86 18.55	28.4.86 20.45	153	698	123 200	6 540	26 800	1 415	3 160	1 745	730	1 200
28.4.86 20.50	28.4.86 21.55	1 090	3 270	210 200	20 710	42 000	5 015	7 195	4 140	1 635	6 320
28.4.86 22.00	28.4.86 22.55	1 310	1 635	101 500	8 830	20 300	3 490	2 835	1 745	719	6 760
28.4.86 23.00	28.4.86 23.55	1 525	1 635	72 500	6 210	14 500	2 725	1 525	927	382	8 500
29.4.86 01.00	29.4.86 01.50	1 045	1 090	39 900	3 380	7 250	1 745	1 090	600	240	6 210
29.4.86 01.55	29.4.86 02.50	1 200	1 090	26 800	2 940	5 145	1 745	883	501	196	6 760
29.4.86 02.55	29.4.86 03.55	840	730	20 300	2 620	3 700	1 525	828	480	196	4 905
29.4.86 04.00	29.4.86 04.50	665	556	16 700	2 180	3 045	1 310	676	414	196	3 705
29.4.86 04.55	29.4.86 05.50	534	469	15 900	1 635	2 600	960	545	316	142	2 945
29.4.86 05.55	29.4.86 06.50	240	207	14 500	1 045	2 100	491	349	207	51	1 415
29.4.86 06.55	29.4.86 07.50	142	120	11 600	534	1 740	316	196	131	25	850
29.4.86 07.55	29.4.86 08.50	109	95	8 700	316	1 230	185	120	-	-	480
29.4.86 08.55	29.4.86 11.10	44	34	3 700	109	515	76	35	20	4	218
29.4.86 11.15	29.4.86 12.10	-[a]	-	1 960	22	275	-	10	-	-	-
29.4.86 12.15	29.4.86 13.10	23	43	2 102	66	290	48	12	-	-	142
29.4.86 13.35	29.4.86 14.25	-	5,3	1 465	39	18	-	6,4	-	-	16
29.4.86 14.30	29.4.86 18.50	5,4	1,7	1 200	14	133	5,3	4,2	-	0,5	34
29.4.86 18.55	29.4.86 23.35	25	400	32 600	2 900	3 060	380	470	270	100	120
29.4.86 23.45	30.4.86 03.45	6,4	250	23 300	2 200	1 995	340	530	310	120	100

-[a] not analysed

From	To	Zr-95	Ru-103	I-131	Te-132	I-133	Ba-140	Cs-137	Cs-134	Cs-136	Np-239
30.4.86 03.50	30.4.86 07.05	-	300	16 600	2 200	1 265	280	330	200	74	-
30.4.86 07.10	30.4.86 13.25	-	60	9 310	530	592	110	160	94	38	-
30.4.86 13.30	30.4.86 17.40	-	64	7 315	600	425	170	250	140	56	-
30.4.86 17.45	30.4.86 22.00	-	40	5 585	620	286	180	300	180	68	-
30.4.86 22.05	1.5.86 02.00	-	14	2 725	140	120	49	72	43	16	-
1.5.86 02.05	1.5.86 04.00	-	15	3 190	110	126	45	42	24	5	-
1.5.86 04.05	1.5.86 06.00	8,4	13	3 990	100	160	39	33	20	5	-
1.5.86 06.05	1.5.86 07.55	9,4	31	6 650	200	253	53	74	44	18	27
1.5.86 08.00	1.5.86 10.00	-	17	5 255	130	186	27	53	31	13	-
1.5.86 10.05	1.5.86 12.15	-	10	4 390	74	120	-	36	20	8	-
1.5.86 12.20	1.5.86 14.15	-	12	4 655	96	1 330	19	39	22	8	-
1.5.86 14.15	1.5.86 17.45	-	17	5 055	98	140	15	41	22	8	-
1.5.86 17.45	1.5.86 22.25	-	23	6 385	110	153	20	44	27	8	-
1.5.86 22.30	2.5.86 03.50	-	28	-	180	220	-	62	41	-	-
2.5.86 03.50	2.5.86 06.55	5,9	43	5 720	210	120	50	92	59	19	-
2.5.86 06.55	2.5.86 11.50	-	28	6 650	140	120	31	79	46	15	-
2.5.86 11.55	2.5.86 16.15	-	19	5 585	130	80	23	82	48	16	-
2.5.86 17.00	2.5.86 21.30	-	8	3 525	52	45	13	33	19	6	-
2.5.86 21.30	3.5.86 07.30	-	10	2 395	57	29	13	38	23	8	-
3.5.86 07.30	3.5.86 12.20	-	31	5 255	170	49	36	120	75	23	-
3.5.86 12.20	3.5.86 16.15	-	41	6 250	220	37	46	160	100	30	-
3.5.86 16.15	3.5.86 20.15	-	39	6 650	190	47	48	150	-	29	-
0.3.86 20.15	4.5.86 00.15	-	31	5 055	150	31	36	120	72	21	-
4.5.86 00.15	4.5.86 07.40	-	24	3 125	129	-	25	97	59	20	-
4.5.86 07.40	4.5.86 12.10	-	19	3 525	82	-	19	74	43	14	-
4.5.86 12.10	4.5.86 16.50	-	14	3 325	57	-	20	51	33	9	-
4.5.86 16.50	4.5.86 22.55	-	12	2 925	52	-	9	53	31	8	-
4.5.86 22.55	5.5.86 08.20	-	6	1 265	27	-	10	26	-	5	-

Determinations of radioactivity in deposition

To determine the nuclide content of the deposition, the normal deposition samples of the monitoring network are supplemented with daily deposition samples in Konala, Helsinki, and in Nurmijärvi. The results of the monthly samples of the monitoring program are in Table 6 and the results of the daily samples in Table 7.

To get a more accurate picture of the regional distribution of the deposition, samples were taken of the surface layers of snow in various parts of the country. If there was no more snow left, wiping samples were taken instead. The gamma nuclide concentrations of these samples are in Tables 8 and 9.

To determine the H-3 and C-14 concentrations of the deposition, air samples are taken in Konala, Helsinki (Table 10).

Determinations of radioactivity in surface water

To map the concentrations of the radionuclides that may enter drinking water, samples were taken of the raw water used by some waterworks as well as of other surface waters (Table 11). During the deposition, most of the lakes that are used for raw water were covered with ice. Because the ice prevents the nuclides from entering the water, it has not been considered necessary to take samples of the water at the early stage.

Gamma-emitting radionuclides in tap water in Helsinki, Konala on 3 May 1986 were as follows (Bq/kg):

J-131	3.4
Te-132	0.2
Cs-137	0.20

Vegetation samples

Grass samples representing a known surface area were taken in the early days of the fall-out situation. At first, samples were taken of dry grass because fresh grass was not available. The purpose was to get a preliminary idea of the contents and amounts of nuclides in the fall-out. The origin of the samples and the detected amounts of radionuclides have been given in Tables 12 and 13.

Milk

The measurements of radioactivity in milk were commenced on 29 April primarily for determining

Table 6.

Gamma-emitting radionuclides in deposition (Bq m^{-2}) in april at stations belonging to the nation-wide monitoring programme

Nuclide	Kuopio	Ivalo	Joensuu	Savonlinna	Jyväskylä	Ivalo	Vaasa	Rovaniemi x)
Zr-95	-	-	-	-	-	-	-	-
Ru-103	602	-	-	540	2 000	-	2 200	28
I-131	20 600	570	1 600	18 900	122 700	570	100 000	3 750
Te-132	8 200	-	450	7 800	45 100	-	32 000	500
I-133	10 100	-	-	-	34 600	-	15 000	320
Ba-140	1 300	-	-	690	3 600	-	4 800	63
Cs-137	1 800	-	34	1 400	8 800	-	6 300	170
Cs-134	860	-	-	790	4 600	-	3 500	110
Cs-136	430	-	-	440	1 700	-	1 400	32
Np-239		-	-	-		-	-	-

x) deposition on 1 and 2 May included in the sample

Table 7.

Gamma-emitting radionuclides in deposition in Helsinki, Konala (area of the collector 0,05 m^2) and in Nurmijärvi (area of the collector 1 m^2) from 29 april 1986 to 3 May 1986.
Sampling time 24 hours from 3 o'clock p.m.

	29.4. - 30.4.86		30.4. - 1.5.86		1.5. - 2.5.86		2.5. - 3.5.86		3.5. - 4.5.86	
	Konala	Nurmijärvi	Konala	Nurmijärvi	Konala	Nurmijärvi	Konala	Nurmijärvi	Konala	Nurmijärvi
Zr-95	250	-	-	-	-	-	-	-	-	
Ru-103	570	150	940	3 200	53	170	-	110	-	
I-131	3 040	670	12 400	35 800	290	350	130	290	130	
Te-132	4 500	1 100	5 800	25 400	230	560	58	410	45	
I-133	240	350	540	2 500	-	-	-	-	-	
Ba-140	500	560	1 350	1 700	78	60	-	44	-	
Cs-137	770	870	1 930	3 900	86	280	30	150	31	
Cs-134	440	720	1 040	2 000	66	160	13	70	-	
Cs-136	140	240	370	650	-	50	-	20	-	
Np-239		-	-	1 200	-	-	-	-	-	

Table 8.

Gamma-emitting radionuclides in snow samples from different sites in Finland (in Bq m^{-2}). Sampling was carried out from the area of 0,5 m^2 or 1 m^2 to the depth of 1 or 2 cm.

	Konala	Vaasa	Kotka	Lahti Tiirismaa	Joensuu Karsikko	Rovaniemi Apukka	Rovaniemi	Pieksämäki	Sodankylä
	28.4.86	29.4.86	30.4.86	29.4.86	30.4.86	29.4.86	2.5.86	30.4.86	29.4.86
Zr-95	30	120	-	1 470	20	-	-	520	-
Ru-103	20	160	87	1 490	-	-	25	580	-
I-131	230	1 960	370	46 500	30	40	1 700	2 300	42
Te-132	50	1 410	920	2 370	20	-	190	2 940	6,7
I-133	40		60	5 660	-	-	-	-	-
Ba-140	20	1 320	290	1 880	-	-	30	2 450	-
Cs-137	20	1 320	600	350	15	-	110	3 900	-
Cs-136	5	220	120	-	-	-	120	780	-
Cs-134	12	690	330	260	5	-	70	2 260	-
Np-239				7 670	-	-	-	1 790	-

Table 9.

Gamma-emitting radionuclides in smear samples in Bq m^{-2}

	Vaasa 29.4.86	Tammisaari 30.4.86	Kotka 30.4.86	Lahti 30.4.86	Kerava 29.4.86	Mikkeli 30.4.86
Zr-95		40	56	27		194
Ru-103	78	150	870	19		300
I-131	1 390	570	3 080	330	56	2 160
Te-132	740	810	9 900	41	20	1 790
I-133	170	50	740			-
Ba-140	250	70	1 290	28		1 606
Cs-137	560	120	5 840	10		1 330
Cs-134	280	80	3 120			780
Cs-136	90	30	1 040			300
Np-239						900

Table 10.

Concentration of ^{3}H (as THO) and ^{14}C (as CO_2) in air at different dates in Helsinki, Konala

Sampling period		^{14}C as CO_2 Bq/m^3	^{3}H as THO Bq/m^3
29.4.	12.35-15.55	0,82	0,78
29.4.	16.30-21.30	0,54	0,62
29.-30.4.	21.30-19.10	0,078	1,6
30.4.-1.5.	20.00-11.30	0,21	1,6
1.-2.5.	13.00-13.00	a	a

a below detection limit

^{14}C and ^{3}H could be observed in air during the days following the accident.

Table 11.

Gamma-emitting radionuclides in raw water for waterworks or in other surface water in Bq/kg

	30.4.1986 Vantaa, Silvola	30.4.1986 Maarian-hamina	30.4.1986 Vaasa	30.4.1986 Punkalai-dun	2.5.1986 Espoo, Bodom	2.5.1986 Espoo, Dämman	2.5.1986 Kemijoki
Zr-95	-	-	-	-	-	-	-
Ru-103	-	0,55	-	28	1,4	2,5	-
I-131	5,7	5,3	36	35	10	25	11
Te-132	1,3	2,0	-	110	5,5	11	-
I-133	-	-	-	-	-	-	-
Ba-140	-	-	-	17	-	-	-
Cs-137	0,58	0,67	1,8	16	1,4	2,5	-
Cs-134	-	-	-	9,0	0,74	1,2	-
Cs-136	-	-	-	5,0	-	-	-
Np-239	-	-	-	-	-	-	-

Bottom water from aeration pool before filtration through soil layers. Sample was taken immediately after rain fall.

Table 12.

Radionuclides in last year's grass in Bq/m^2

Origin of sample	^{95}Zr	^{103}Ru	^{131}I	^{132}Te	^{133}I	^{140}Ba	^{137}Cs	^{134}Cs	^{136}Cs	^{239}Np
Helsinki, Konala 28.4.1986	10	11	1 640	29	295	15	14	12	-	90
Olkiluoto 29.4.1986	1 080	1 360	11 800	7 370	1 250	1 300	920	560	180	-
Joensuu, Ilosaari 30.4.1986	30	12	87	32	20	25	6	4	-	-
Pieksämäki 30.4.1986	290	2 350	34 700	17 300	-	8 100	11 900	6 950	2 560	-

Table 13.

Radionuclides in vegetation in Bq/m^2 (Bq/kg)

Type and origin of sample	^{95}Zr	^{103}Ru	^{131}I	^{132}Te	^{133}I	^{140}Ba	^{137}Cs	^{134}Cs	^{136}Cs	^{239}Np	Comments
Moss (fresh) 29.4. Helsinki, Konala	11	8,4	600	26	63	10	20	9,8	3,0	41	
Lichen 28.4. Helsinki, Konala	(30)	(61)	(1 160)	(100)	(215)	(62)	(113)	(11)	-	(395)	in Bq/kg
Grass (fresh) 30.4., Porvoo, Kiala	100	4 200	11 800	7 200	670	800	1 800	920	330	870	
Grass (fresh) 30.4., Kotka	-	4 200	42 100	46 600	3 100	2 000	18 200	10 600	3 400	1 920	
Grass (fresh) 30.4., Mikkeli	(570)	(1 280)	(26 900)	(7 620)	(2 100)	(2 220)	(4 700)	(2 600)	(800)	(2 690)	in Bq/kg
Wild chervil (Anthriscus silvester), 30.4. Helsinki, Konala	(170)	(1 460)	(10 100)	(9 750)	(700)	(1 870)	(2 020)	(1 130)	(415)	-	
Hair Moss 29.4. Olkiluoto		940	2 430	24 200	16 700	2 470	1 740		2 100	1 200	110

radioiodine, although the grazing season has not yet begun in Finland. The earliest sample represented the production from the weekend 26 - 27 April. Samples are taker daily and they cover the fall-out area. Outside the actual fall-out area, samples are also taken in the Oulu and Lappi provinces in northern Finland.

The values of iodine-131 have been corrected to show the activity of the day following the production (beginning of consumption).

Iodine-131 was already detected in milk on 28 April (< 10 Bq/1). A distinct rise occurred on 29 and 30 April, the maximum values being 21 Bq/1 and 40 Bq/1. Most of the results were < 10 Bq/1. From 1 to 3 May, the mean concentration varied between 20 and 30 Bq/1. The maximum value measured on 2 May is 54 Bq/1. At the northern and eastern borders of the fall-out area, the levels have remained below 10 Bq/1 during the first days of May.

The amount of iodine-133 has usually remained below 1 Bq/1, the maximum being 7 Bq/1. Tellurium-132 has varied between 0 and 2 Bq/1. In some samples, cesium-137 has slightly increased, the highest concentrations being 1.5 Bq/1. The ^{137}Cs-levels will be determined more accurately later, as well as strontium 89 and 90.

INTERNAL RADIATION

The amounts of activity accumulated in humans have been studied with whole-body counter measurements. So far the studies have concentrated on the internal activity of tourists and workers returning from the Kiev area and from other parts of Eastern Europe. The ^{131}I-concentrations in the thyroids of the 25 persons who have been measured have varied between 3 and 20 kBq, the mean being 8 kBq. The thyroid dose caused by the ^{131}I-activity varied between 5 and 30 mSv. The level of internal ^{137}Cs-activity measured was about 1 kBq. The radioactive substances that have been detected in persons returning from other Eastern European countries were the same as those found in persons returning from Kiev, but the amounts of activities have been considerably lower.

A few persons living in Southern Finland were also been measured and it was concluded that the ^{131}I-activities in the thyroid were generally below 400 Bq. The ^{137}Cs-levels are correspondingly lower than in persons returning from Kiev. The future changes in activity levels will depend on changes in the activity levels of milk and other foodstuffs.

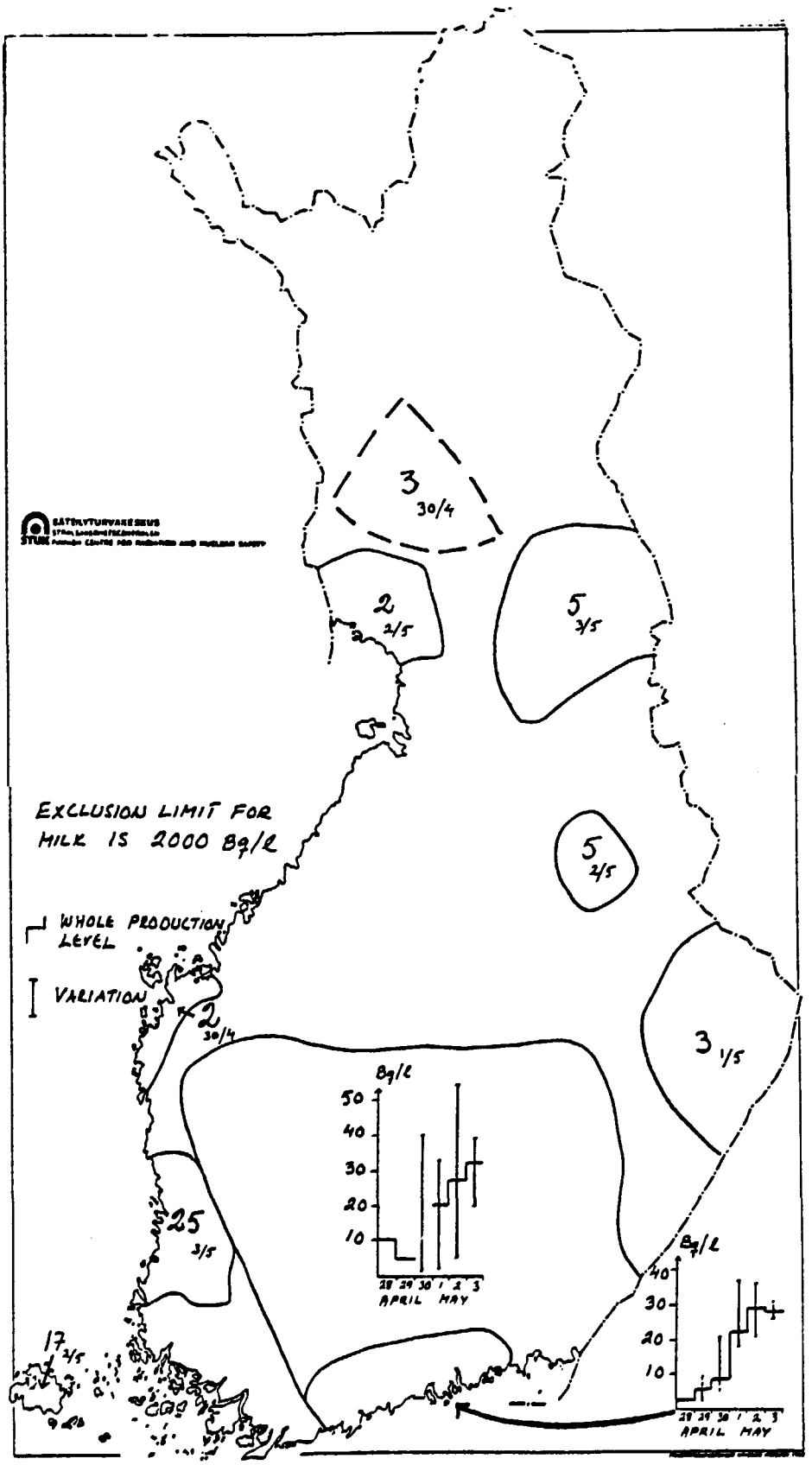

Figure 16.
Amounts of iodine-131 in milk from 28 April to 3 May 1986 (Bq/1).