serie

SSI-rapport 86-12

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Chernobyl - its impact on Sweden

ISSN 0282-4434

Price SEK 00

Title page

NATIONAL INSTITUTE OF
RADIATION PROTECTION
STATENS STRALSKYDDSINSTITUT

Document number SSI-rapport 86-12	
ISSN 0282-4434	
Date August 1, 1986	

Author

Division

Title of the document

Chernobyl - its impact on Sweden

Abstract

In case of a radiological emergency in Sweden, the Swedish National Institute of Radiation Protection (SSI) has the responsibility of organizing a special task force with experts both from SSI and from other authorities. Reports of increased radiation levels reached SSI around 10 am on April 28, 1986, and the task force convened at 1030 am. A large number of measurements were made all over the country, and temporary grazing restrictions were imposed so as to avoid excessive doses from the food chain grass-cow-milk. Attention is now concentrated on regions with high cesium activity and on foodstuffs in general. A very tentative estimate of the collective dose commitment is 10 000 man.Sv. It turned out that the general public was not always satisfied with the information provided by the authorities, in spite of complete openness.

Keywords (chosen by the author)

Chernobyl
Accident
Measurement
Countermeasure

Number of pages

24

Stockholm, August 1986

To the readers of CHERNOBYL - ITS IMPACT ON SWEDEN

This is the first comprehensive publication in English dealing with the radiation risks in Sweden from the Chernobyl accident and the countermeasures taken. It purports to give an overview of the very extensive information that is available from Sweden in various publications as well as in the form of raw data. The expected readers are radiation protection experts in other countries and in international organisations.

Data and analyses have been presented in English also from other Swedish bodies such as the National Defence Research Institute and the National Food Administration. The report contains addresses to several such organisations.

An elementary description of the accident consequences has been published by the Swedish National Institute of Radiation Protection. It is a direct translation of a report aimed at the various non specialist Swedish authorities handling the accident consequences. The report is entitled "Chernobyl - fallout, measurements and consequences". This publication in English might be of interest also to specialists, as an example of a simplified account of the events.

Scientific reports on what happened in Sweden will continue to appear at conferences, in scientific journals and so on. Several articles have already been prepared for publication and a large number of scientific institutions are involved.

Gunnar Bengtsson
Director General
Swedish National Institute of Radiation Protection

Chernobyl - its impact on Sweden

1. Emergency organization

The organization for radiological emergencies in Sweden is mainly based on the needs that may arise from the 12 reactors in the national nuclear power program. The organization has a regional character in that the responsibility in an accident situation rests with the highest county authority - the county council - in each of the five counties in which there is a major nuclear installation (the four power plants Oskarshamn, Barsebäck, Ringhals and Forsmark, and the Studsvik research center).

In case of an emergency, each of these county councils has at its disposal the county alarm center, the local radio stations and the police, coast guard and fire-fighting organizations. Special communication channels between the various authorities and the Nuclear Power Facilities have been installed and extensive training of the relevant personnel categories has taken place.

On the national level the National Institute of Radiation Protection (SSI) has the overall responsibility for the emergency planning outside the nuclear power plants and for providing the county authorities with advice and instructions for planning. In the event of an accident the SSI shall give advice to the county council rescue command. For that purpose the SSI has the responsibly of organizing a special task force with radiation protection experts from the institute, reactor engineering experts from the Nuclear Power Inspectorate (SKI) and specialists in meteorology and protection of the population. The tasks for this group are to analyse the emergency situation, give prognoses of the radiological consequences and to co-ordinate the various activities with measuring ionizing radiation. This task force is also supposed to be called in for all emergencies or accident situations in which the radiation of the public from ionizing radiation must be taken into consideration.

With the exception of the special task force at SSI the emergency planning described above covers only emergencies and accidents in the Swedish nuclear power industry and 5 out of Sweden's 24 counties. In other nuclear emergencies of non-domestic origin the "nuclear" counties may extend their authority to neighbouring ones. For the country at large, the Government takes the responsibility through the National Institute of Radiation Protection. Situations of this kind arose in the early 1960s, when considerable fall-out from above-ground weapons testing was foreseen. More recently there have been two instances when there was a risk that nuclear-powered satellites would reenter the atmosphere over Swedish territory. The latest situation is that arising from the Chernobyl accident, and this has put the heaviest demand on the organization so far.

2. Early chronology of the Chernobyl emergency

At around 10 a.m. on April 28, the SSI was notified that increased radiation levels were observed at the Forsmark nuclear power plant. The local county alarm centre was also notified. Gate monitors had sounded the alarm as employees were leaving the plant after having crossed open ground between the buildings and the gate. Although no abnormal radiation levels were observed inside the reactor buildings or from the stacks, a plant alert was declared, resulting in the evacuation of all personnel not required for the immediate operation of the plant. The local radio station was informed of the observations and the measures taken.

The SSI special emergency task force was convened at the SSI Stockholm headquarters in accordance with preexisting plans, at 10.30 a.m. Shortly thereafter information was received about abnormal radiation levels at the Studsvik research center, about 200 km down the coast from Forsmark. Contact was established with the other three nuclear power plants, who also during the afternoon reported inreased air and ground activity in their vicinity. In addition, contacts were taken with the Finnish Centre for Radiation and Nuclear Safety and with the Risö Research Centre in Denmark. They confirmed that increased background radiation and airborne contamination had been registered in both Finland and Denmark.

The National Defence Research Institute (FOA) operates a national network of highly sensitive air sampling stations designed for verification of nuclear test bans. When FOA at 12.15 was notified of the presumed release at Forsmark they immediately analyzed the sample just taken from the Stockholm station. From several radionuclide ratios it was evident that a reactor accident had occured somewhere.

The FOA system incorporates a link to SMHI, the Swedish Metrorological and Hydrological Institute, on which automatically each morning receptor oriented air parcel trajectories are transfered. The Stockholm trajectories that morning sshowed the air coming from Latvia/Lithuania, White Russia and Ukraine in the Soviet Union. All Swedish reactors could thus be excluded and several sites in USSR (Ignalia, Rovno, Chernobyl, Kursk and Novovoronezhiskiy) were, according to this analysis, candidate accident sites.

These conclusions were reported to SSI around 1300.

The FOA air sampling network consists of several stations around the country (Fig. 1). The filters are normally changed three times a week but starting on April 28 samples were taken much more frequently, for periods of 1 - 3 hours. In these early filters around 40 different radionuclides were identified.

The FOA surveillance system also includes air filter collectors which can be mounted under the wings of "Lansen" jet fighter aircraft flown by the Air Force. On the afternoon of April the 28th these planes collected samples along the eastern border 300 m above the Baltic Sea. A scan was also made at different altitudes up to 12 km. This was done partly to exclude the remote possibility of the event being due to accidental reentry of a reactor powered satellite.

Direct in-cloud measurements were carried out by FOA in the evening of the 28th, utilizing a mobile germanium spectrometer on a Marine helicopter. On that flight doserate meters also showed the contaminated cloud to be between 200 and 1000 m above sea level with a maximum at around 700 m.

Dating from the times of frequent above-ground weapons testing around 1960, the SSI has had a network of 25 permanent, continuously registering gamma stations (Fig 1). A systematic collection of data from these stations was initiated already before lunch.

The SSI emergency organization was successively enlarged to include experts from the Nuclear Power Inspectorate (SKI), the National Defense Research Institute (FOA), the National Board of Civil Defence (Cfs) and the National Institute for Meteorology and Hydrology (SMHI). Many external organizations were drawn upon for measurements: FOA, the nuclear power stations, the Swedish Geological Co (SGAB), the Department of Radiophysics at the University of Lund and many other research institutes.

The SSI emergency center was manned around the clock for the first few weeks. As the fall-out situation became clearer, cooperation was established with the national authorities for food administration, agriculture and occupational health.

3. Measurements and results

Ground and air measurements

The radiation level started to rise at some of the gamma stations on April 27 as the first cloud of contaminated air from the Chernobyl accident reached Sweden. The air activity reached a maximum around April 29. Another, cloud of contaminated air entered Sweden from the south-east resulting in a lesser maximum in air contamination around May 9. This second maximum affected mainly the south and south-west parts of Sweden. During the first few days the measurement of air activity was of foremost importance, both in order to see how the situation was developing and to estimate initial doses from the cloud (direct and inhalation dose). The National Defence Research Institute provided data from their ground-level stations and from daily sampling flights at altitudes between 100 and 800 m. The filters were analyzed for nuclide composition. The dominant radionuclide in the cloud was I-131. In the Stockholm area, a maximum particulate I-131 concentration in air of 11 Bq/m^3 was measured. The maximum total iodine concentration was probably around 50 Bq/m^3. Autoradiography of the filters showed hot particles dominated by radionuclides such as molybdenium, cerium, ruthenium and zirconium.

Figs. 2 and 3 shows the variation of I-131 and Cs-137 in Stockholm and at Ljungbyhed in southern Sweden during the first two weeks.

A Pu-239,240/Cs137 activity ratio, obtained from measurements on rainwater and filters, made by Forsmark and FOA, was of the order of 10^{-4}.

The outdoor radiation level was continuously followed by the gammamonitoringstations. The highest increase in this system, a factor of ten, was registreted at Umeaa in the northern Sweden. Some other stations gave no detectable increase at all. An exemple of the variation of the outdoor radiation level is given in Fig. 4. The highest initial increase of the outdoor radiation level in the country was a factor of approximately 100 measured in the Gävle area.

An over-all picture of the ground deposition in all of Sweden was obtained by aerival scanning from a height of 150 m. The scanning operation, which was carried out by the SGAB, revealed a considerable variation in ground activity, due to local rain during the cloud passage. Fig 5 shows the exposure rate calculated from aerival scanning. By combining the aerial scanning result with the in-situ measurements it was also possible to calculate the distribution of some dominant radionuclides on the ground. An example of such a distribution is depicted in Fig 6. The high-concentration areas were also surveyed by road vehicles.

As can be seen from Figs. 5 and 6, the highest deposition was found around the towns of Gävle and Sundsvall, where the ground activity of Cs-137 exceeded 85 kBq/m^2, with local levels reaching 200 kBq/m^2. The maximum cesium concentrations are more than 100 times the average cumulative level from all past weapons tests. The far north of Sweden was only very slightly contaminated.

Using their mobile germanium detector system FOA made radionuclide specific deposition measurements in-situ at close to 100 places around the country. These and other measurements showed that the short-lived radionuclides were generally dominated by I-131 and the long-lived by Cs-137. The initial (April 30) I-131/Cs-137 ratios were typically around 5. A strong variation in the ratio of short-lived Te-132 to I-131 was observed. In the wet-deposition areas, the initial tellurium activity was of the same order of magnitude as I-131, the ratio being up to 15 times higher than in the

dry-deposition areas. This meant that the activity in the high-intensity regions initially decayed somewhat faster than in the low-intensity regions. After six weeks, the ground activity was dominated by Cs-137 and Cs-134, with the ratio 1:0.6. In parallel with the large-scale surveys, a large number of detailed measurements were carried out by many organizations throughout the country, mainly of total gamma dose rates 1 m above ground. An example of the radionuclide composition on an air filer in the Stockholm area is given in Table 1.

Foodstuffs

Very early in the emergency, the SSI decided on action levels in terms of the expected dose equivalent. As a result, attention was focussed on the food chain grass-cow-milk. The maximum acceptable ground deposition for I-131 was initially taken to be 10 kBq/m^2, assumed to correspond to 3 kBq/m^2 of grass and 2 kBq/l of milk. For total cesium, the corresponding figures are 3 kBq/m^2, 1 kBq/m^2 and 0.3 kBq/l, respectively. There is considerable uncertainty in the conversion from ground to grass activity, the ratio varying with the conditions at the time of the fall-out. (In most parts of the country the ratio of grass-to-ground activity turned out to be less than indicated above). An extensive mapping of grass deposition by means of grass sample measurements was therefore given high priority, starting from the south where the outdoor grazing season had just begun. Where the limits were exceeded, milk-cows were kept in their cow-sheds. In the southern parts of the country the measured values mostly lay below the limits, or fell below them within the first few weeks.

The SSI has been monitoring radionuclides in dairy milk since 1962. The sampling program was extended successively during the first few days of the emergency, and after May 2 covered all 42 commercial dairies of the country. Because of the grazing restrictions imposed initially, the iodine concentrations in dairy milk stayed well below the limit of 2 kBq/l, even where the ground deposition was high. High measured values were around 0.2 kBq /l. In a single sample from a farm a I-131 concentration of 2.9 kBq/l has been measured. An example is given in in Fig 7.

Attention is now concentrated on the regions with high cesium activity. In the limited areas where the grass activity might still warrant restrictions, the measured milk concentration is now the direct indicator for possible countermeasures. A number of farms have been selected for long-term, detailed monitoring. Direct milk measurements have generally given more favourable results than were predicted from ground and grass activity. In general, cesium concentrations in dairy milk have increased when the cows were let out for out-door grazing, but have stabilized at a low level as can be seen from Fig. 8.

The ratio Sr-90/Cs-137 in different samples is of the order of 1 per cent. In some milk samples, however, with low activity concentrations the measured ratio have been higher. This is caused by the Sr-90 background from the atmospheric nuclear weapons tests in the 1960s.

The activity in drinking water from municipal water supplies and private wells is now lower than 0.01 kBq/l. In May some wells vere temporarily contaminated by surface water during the snow-thaw period resulting in higher concentrations.

As for other foodstuffs, products that might have been affected have not yet been ready for the market to any appreciable extent. An extensive, long-term monitoring program is being carried out by the National Food Administration (SLV) in collaboration with SSI. This comprises both tests of the various foodstuffs and so-called food basket investigations. In principle, the same action level is applied to all foodstuffs as to milk (i e, 0.3 kBq Cs-137 per kg or litre).

Meat from domestic animals having grazed in the more contaminated areas has generally shown concentrations well below the limit. However, in some instances cesium values near the limit have been observed for beef, which has led to more detailed control in the pertinent regions. In sheep, the problem may be more pronounced due to different grazing habits. The meat from several adult animals has had to be discarded after slaughter because the limiting value has exceeded (by at most a factor 4). A slight degradation of the situation may be expected later in the season as grazing takes place closer to the ground and young animals feed more extensively on grass.

For game, the limiting value is clearly exceeded in the highly contaminated regions. So far, samples have been obtained mainly from animals killed by traffic. Although the mean is below the limit, the following peak values have been reported: for hare; around 5 kBq/kg, venison; 8 kBq/kg, woodcock; 16 kBq/kg, and moose; 1 kBq/kg. The situation will be closely monitored. No meat with an activity concentration exceeding 0.3 kBq/kg will be marketed.

In accordance with a recent decision by the National Environmental Protection Agency individual high values do not justify general restrictions for the hunting season. For woodcock though there is a recommendation issued in June not to hunt those birds due to their high cesium concentrations.

For fish in the sea only very low cesium concentrations have been measured. Also fish in fresh water in the south and northernmost parts of Sweden have concentrations well below the limit. In some other areas Cs-137 concentrations up to many kBq/kg have been measured. There are, however, large differences between different types of fish and also between different lakes, even when the lakes are close together. The National Food Administration has an extensive measuring program in progress.

For vegetable foodstuffs, values above the permissible level have been obtained in the more highly contaminated areas primarily for early species that were well developed at the time of the fall-out, such as chives, parsley and nettles (at most 3-4 kBq/kg). For later species, such as rhubarb, lettuce, berries and potatoes, no alarming values have so far been reported, but the situation will be closely watched throughout the growing season.

The most pronounced long-term problem seems to arise in connection with reindeer breeding, which is the main livelihood of the Lapps. Already after the weapon fall-out in the 1960s, it was found that the cesium uptake is exceptionally high in reindeer, mostly due to their uniform diet of reindeer lichen. Reindeer killed in the highly contaminated regions after the accident show cesium concentrations at or above the permissible, in a large fraction of the cases more than 10 kBq/kg. The levels cannot be counted on to decrease to levels below 0.3 kBq/kg over the coming years in the highest contaminated areas without special countermeasures.

As may be expected from the general activity situation, no alarming concentrations have been found in humans. The values in mothers' milk have been very low - below 0.025 kBq/l of I-131. The measurements were carried out shortly after the cloud passage. Some whole-body measurements are in progress.

4. Countermeasures and their effects

In an accident situation the existing limits for permissible releases cannot automatically be applied. The ALARA philosophy must be the guiding principle, i.e. the radiation doses should be kept as low as is reasonably achievable, with due consideration to economic and social costs.

In the face of the Chernobyl fall-out situation there was no firm basis for detailed considerations of a formal nature. In other words, neither available information nor time permitted cost-benefit or similar analyses at the level of scientific sophistication attempted under normal circumstances. Instead, common sense and rule of thumb analyses supplemented by very coarse cost-benefit considerations had to be used. It is interesting to note that both the types of countermeasures and the action levels decided on in various countries still agree reasonably well.

One of the first questions was whether to recommend intake of inactive iodine. At no time was this considered necessary. In spite of repeated statements that there was no reason to take iodine pills, drugstores reported increased sales of such pills.

Very few countermeasures were regarded as necessary (or feasible) against radiation from the cloud or from ground depositions. Thus, no recommendations against outdoor activities were issued, even for pregnant women or children. (However, opinions expressed by independent researchers, e g that children should not play in sand pits, were publicized). A few cases of industrial hygiene problems were dealt with. One was connected with the replacement of air filters in use in large buildings such as hospitals during the cloud passage. Personnel were advised to wear breathing masks and protective gloves when handling the filters. Recommendations were also given for travellers: People were advised not to go closer to Chernobyl than 100 km, and to go within 500 km of the site only after personal consideration of the purpose of the trip.

Intake of food and beverages is the route where countermeasures are easiest to apply and most effective, and this is the area where the most extensive recommendations were given.

It was judged at an early stage that the normal dose limits to the public ought not to be exceeded through the intake of contaminated food. This then meant that the annual intake dose should not exceed 5 mSv for the next couple of years, and 1 mSv on a long-term basis. These limitations should apply to the most exposed group (young children). Fulfilment of the former condition would probably imply fulfilment of the latter.

The following rounded-off conversion factors were used between equivalent whole-body dose to a 1-year-old and activity intake:

I-131	2×10^{-7} Sv/Bq
Cs-137 , Cs-134	10^{-7} Sv/Bq.

For cesium, then, an annual dose of 5 mSv would correspond to a daily intake of 137 Bq. Assuming an intake of some 0.3 kg per day (for a 1-year-old) and rounding off, gave the activity limit of 0.3 kBq of Cs-137 per kilogram (litre) quoted above.

For iodine, the activity concentrations in milk and other foodstuff could be foreseen to diminish rapidly. An activity limit of 2 kBq/kg or per l, established in earlier recommendations was therefore accepted.

No other radionuclides were expected to make major contributions to the dose.

In order to observe the above limits, a number of countermeasures were decided upon. It was recommended that cows should not be allowed to graze out-of-doors until a region was cleared on the basis of grass sample measurements. While grazing restrictions were in force in a region, people were recommended to refrain from eating green vegetables, such as parsley, chives, dandelions and nettles, as well as morels. Recommendations were also issued against drinking rainwater.

Since the grazing season had not yet, or just barely started at the time of the accident, the losses incurred by the farmers in most parts of the country were limited. In the most heavily contaminated regions, however, where clearance could take many weeks, (the last region was declared free for grazing on June 25) there were difficulties in procuring hay for stalled cattle, and the productivity of the cows decreased. In a few cases grass had to be mown and discarded. Special harvesting methods were developed, leaving a higher stub than usual to avoid contamination with radioactive soil. The use of sewage sludge for soil improvement is common in Swedish agriculture. Since rain-water from large areas is drained to the sewers, activity concentrations in the sludge in some cases rose to levels that made it unacceptable for the purpose. The limits have been set at 4 kBq/kg (wet weight) and 20 kBq/kg (dry weight).

At an early stage the Government declared that compensation would be paid for costs incurred because of the accident. The total costs have not yet been established.

The further aim of reducing the radiation doses from intake of food will be subject to the results of the continuing monitoring program. Since high cesium concentrations have been observed in some freshwater fish, and fishing is a highly decentralized activity, the National Food Administration has issued a statement that it is not advisable to eat fish from 14 communities in the highest contaminated area. In some other communities fish should not be eaten more than once a week.

The most severe long-term problem is foreseen in connection with reindeer breeding in the most contaminated counties. The problem will not become acute until the slaughter season in the fall and thus no formal recommendation is given yet. However it seems likely that a sizeable number of animals will have to be discharged.

One of the major economic detriments experienced in Sweden because of the accident has been the decline in foreign tourism to Sweden. (Greatly exaggerated reports of the radiation levels in Sweden have been published in various countries).

5. Estimated radiation doses

The estimated total doses are still tentative. Doses received during the passage of the cloud, either from direct radiation or from inhalation, have been negligible. Rather, the doses are almost entirely due to ground deposition.

The dominating factor is the direct ground radiation dose from cesium. Food intake doses, although not yet calculable with great accuracy, are expected to contribute of the order of a few tenths of a mSv in 1986. Investigations have been started to estimate the activity in a typical Swedish diet in order to obtain a better foundation for dose calculations.

For the regions of highest contamination (initial ground dose rate 0.01 mSv per hour), the total equivalent whole-body dose for the whole of 1986 is calculated to be 4 mSv, assuming 8 hours a day out-of-doors and a population living in small wooden houses that offer little protection. For 2 hours a day out-of-doors, and an apartment house, the corresponding dose is 1.1 mSv. About 75% of the 1986 dose will be received after June 1.

The collective effective dose commitment (for all years to come) to Swedes is estimated to be about 10 000 manSv. Of course this figure is only a rough estimate.

6. Information to the public

It soon became clear that the attitude of the general public to the emergency would be a grave problem. One of the main causes of the problem is the general unfamiliarity with radiation and radiological risks. A lesson which has been learnt therefore is that the issuing of information to the public must be improved in this respect.

The policy of the SSI and other authorities has been complete openness in providing information as it became available. This did not always improve the credibility of the SSI and other authorities. The following circumstances aggravated the situation:

- Initial estimates of radiation levels, doses and risks had to be revised as more data became available.
- The organizations involved in data collection reported not only different quantities (activity, dose rate etc), but also used different units (rem, rad, gray, sievert, becquerel, etc), giving apparent inconsistencies in numerical values and creating confusion.

- Assurance that the individual risk, even in high-contamination areas, was negligible, appeared to be in contradiction with the stipulated countermeasures.
- Critics of generally accepted radiobiological risk factors received relatively great publicity, questioning the recommendations and estimates of the consequencies issued by SSI.

The normal SSI facilities and staff were found to be inadequate for the occasion. Telephone calls from worried or frightened individuals blocked the switchboards. As many as 2 000 calls a day were received. Many more did not get through. The questions ranged from the advisability of making trips abroad to possible radiological explanations to sudden illnesses. Another lesson learnt therefore, is that competence to give authoritative information must be decentralized to a higher degree.

Several research projects on public perception, and how it was influenced during the emergency, have been initiated.

7. Responsibilities of different authorities and organizations

Under normal circumstances, SSI supervises the use of radiation and issues licences etcetera in accordance with the law on radiation protection. Early consultations made it clear that the Government agreed with SSI that dramatic action such as evacuation of large groups of people, which would have meant invoking the law on atomic defence, were not called for. The most important role for SSI was therefore to coordinate activities and give advice and recommendations. In some cases, formal decisions rested with SSI, in other cases other government bodies took decisions based on SSI recommendations.

The National Defence Research Institute (FOA) supports SSI with measurements and calculations. Other organizations involved in sampling and measurement are hospitals and universities, power plants, research institutes and the Swedish Geological Co (SGAB) who supplied a whole series of maps with isolives for doserates based on aerial measurements.

The National Food Administration (SLV) establishes formal limits for the radioactivity in food (after consultation with SSI). They also design and run control programs for foodstuffs.

The Board of Agriculture (LBS) issues recommendations to farmers, reindeer owners etcetera on how to minimize the effects of the Chernobyl accident. They are also responsible for disbursement of compensations and damages. In these activities they use their field organization comprising a number of local agricultural panels.

The Board of Occupational Safety (ASS) issues recommendations on industrial hygiene, for instance as to the need (or lack of need) for protective clothing.

The Environmental Protection Board (SNV) issues licences, for instance when sludge must be deposited, and is also responsible for exceptional changes from the game hunting seasons.

The Nuclear Power Inspetorate (SKI) - which would have extensive duties in a domestic accident - has given advice on the likely evolution at the accident site.

The Board of Health and Welfare (SoS) is co-responsible for the supply of inactive iodine, and has provided information for medical staff.

The Swedish Meteorological and Hydrological Institute (SMHI) supplies and interprets necessary weather data.

The county councils are equipped with nature conservancy units and county veterinarians and give advice to local (municipal) authorities. The latter have, in varying degree, taken part in sampling and in some cases measurements.

Many other public and private organizations have also been involved. At the practical level, the Board of Civil Defence (SRV) have provided very important assistance in the shape of extra staff for basic functions at SSI.

The full Swedish names and addresses of these authorities are given in Appendix 1.

Names in English and Swedish, mailing addresses and telephone numbers of some of the organizations involved in actions and countermeasures after the Chernobyl accident

National Institute of Radiation Protection (NIRP)
Statens strålskyddsinstitut (SSI)
Box 60204
S-104 01 STOCKHOLM Sweden +46 8 24 40 80

National Defence Research Institute, Dept 215
Försvarets forskningsanstalt, avd 215 (FOA 215)
Box 27322
S-102 54 STOCKHOLM Sweden +46 8 63 15 00

Swedish Geological Company
Sveriges geologiska aktiebolag (SGAB)
Kornhamnstorg 53
S-111 27 STOCKHOLM Sweden +46 8 14 42 20

National Food Administration
Statens livsmedelsverk (SLV)
Box 622
S-751 26 UPPSALA Sweden +46 18 17 55 00

National Board of Agriculture
Lantbruksstyrelsen (LBS)
S-551 83 JÖNKÖPING Sweden +46 36 16 94 20

National Board of Occupational Safety and Health
Arbetarskyddsstyrelsen (ASS)
S-171 84 SOLNA Sweden +46 8 730 90 00

National Environmental Protection Board
Statens naturvårdsverk (SNV)
Box 1302
S-171 25 SOLNA Sweden +46 8 799 10 00

Nuclear Power Inspectorate
Statens kärnkraftinspektion (SKI)
Box 27106
S-102 52 STOCKHOLM Sweden +46 8 63 55 60

National Board of Health and Welfare
Socialstyrelsen (SoS)
S-106 30 STOCKHOLM Sweden +46 8 783 30 00

Swedish Meteorological and Hydrological Institute
Statens meteorologiska och hydrologiska institut (SMHI)
S-601 76 NORRKÖPING Sweden +46 11 15 80 00

National Board of Civil Defence, Rescue and Fire Service
Statens räddningsverk (SRV)
Karolinen
S-651 80 KARLSTAD +46 54 10 30 00

All addresses above are complete (i e, the zip code is sometimes the full address). In the phone numbers, 46 is the country code for Sweden (i e, numbers become complete when the routing number for international calls is substituted for + in the numbers).

Table 1

Radionuclide composition, as measured on an air filter from Grindsjön, Stockholm. Sampled 13.25 April 28 - 10.00 April 30 (FOA)

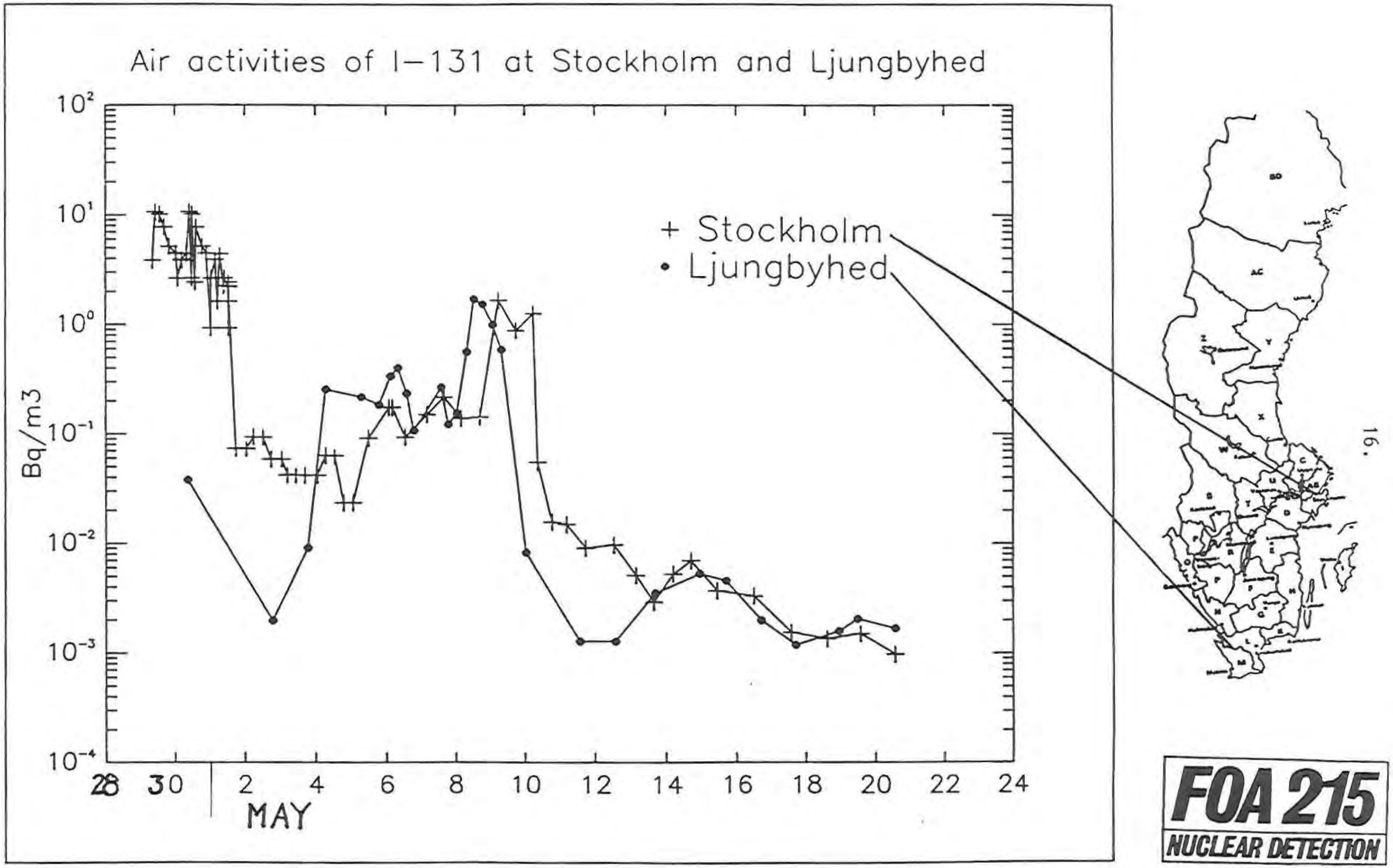
Nuclide	Activity relative to Cs-137	Nuclide	Activity relative to Cs-137
Cs-137	1.0	Zr-95	0.13
I-131	2.9	Ce-141	0.13
Te-132	2.3	Ce-144	0.076
Cs-134	0.49	Ru-106	0.056
Ba-140	0.47	Pu-241	0.015
Np-239	0.40	Cm-242	0.0016
Te-129^m	0.32	Pu-239	0.00022
Ru-103	0.30	Pu-240	0.00016
Mo-99	0.18	Am-241	0.00014
Cs-136	0.17	Pu-238	0.00010
Nb-95	0.16	Cm-244	0.000016

Note: Due to sampling techniques the I-131 concentration is underestimated by a factor of approximately 5.

Fig. 1

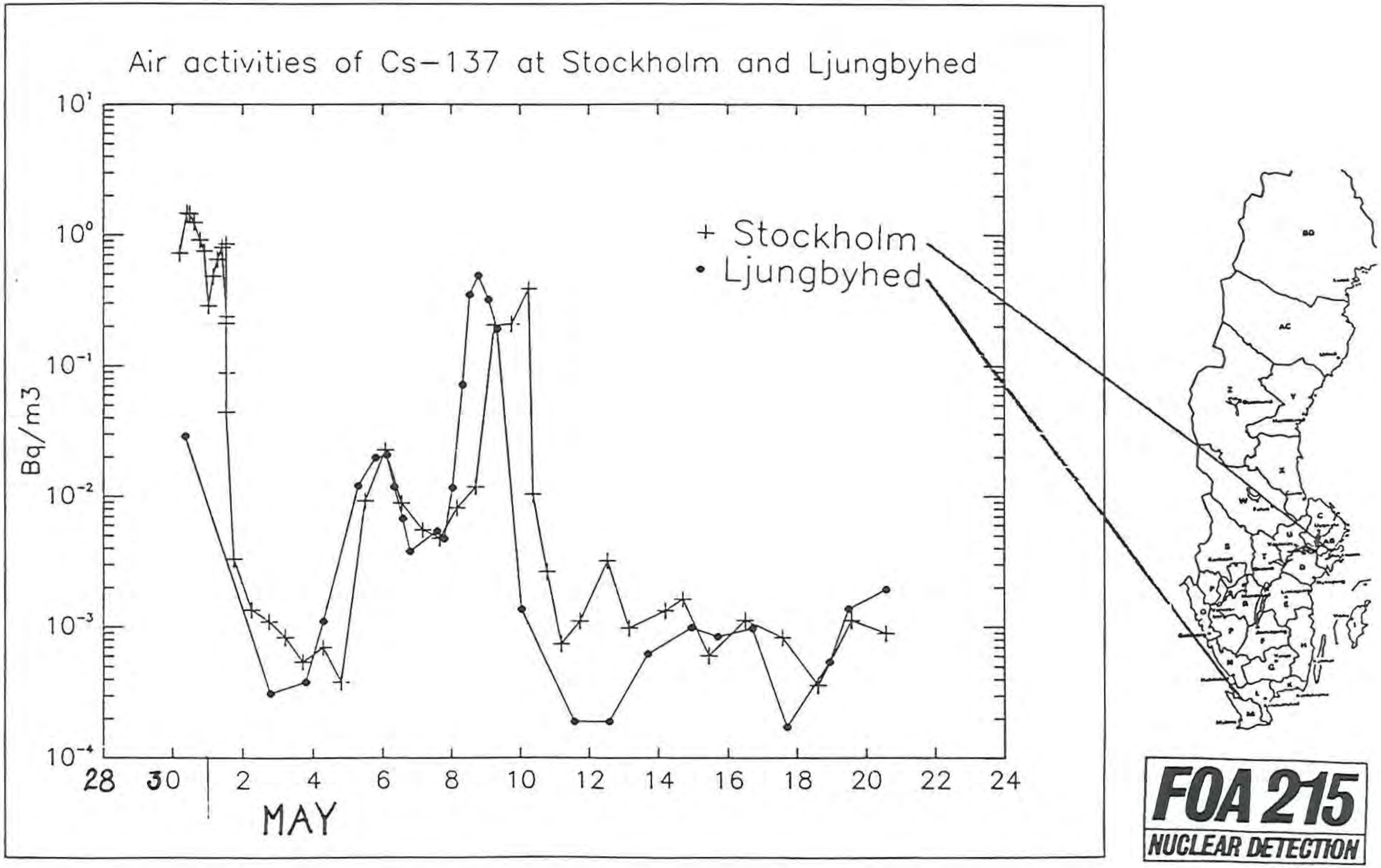
● Location of SSIs (National Institute of Radiation Protection) permanent 25 gamma-stations.

▲ Location of FOAs (Defence Research Institute) permanent 7 air-samples stations.



FOA 215
NUCLEAR DETECTION

Fig. 2



FOA 215

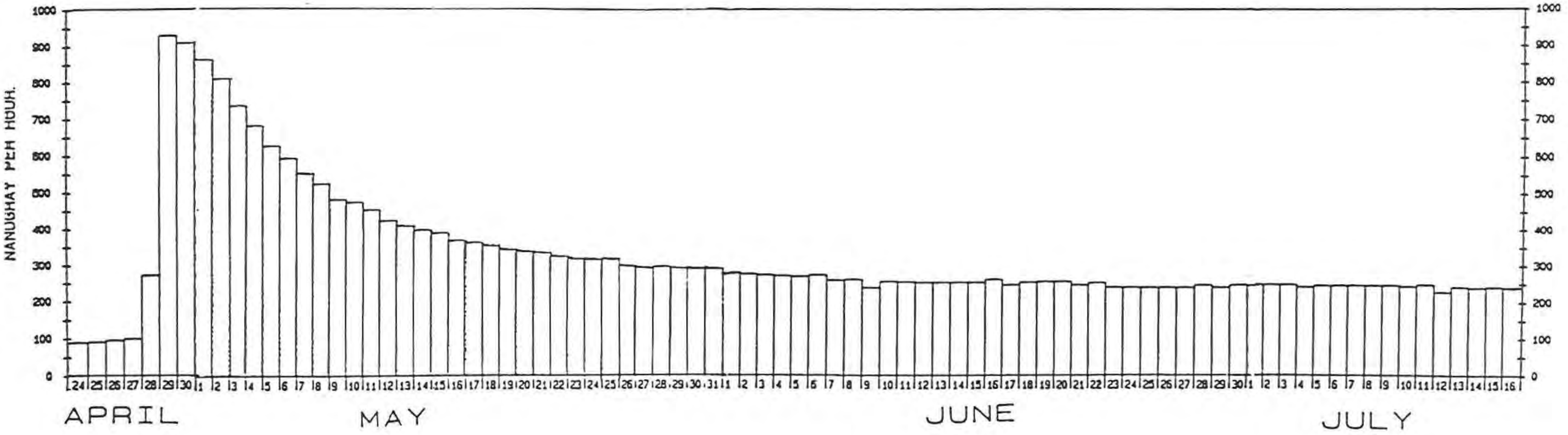
NUCLEAR DETECTION

Fig. 3

National Institute of Radiation Protection, Stockholm, Sweden

FOUR-MONTH GAMMA LEVELS FOR STATION: UMEAA.

1986



Doserate in air (kermarate) at SSIs permanent registering gamma station in Umeå.
The station measure at 2.5 m heigth above ground level.

Fig. 4

CONTAMINATION MAP

**Estimated ground intensity on May 9, 1986, in µR/h.
The map is based on aerial surveys from May 9 to June 3, 1986.**

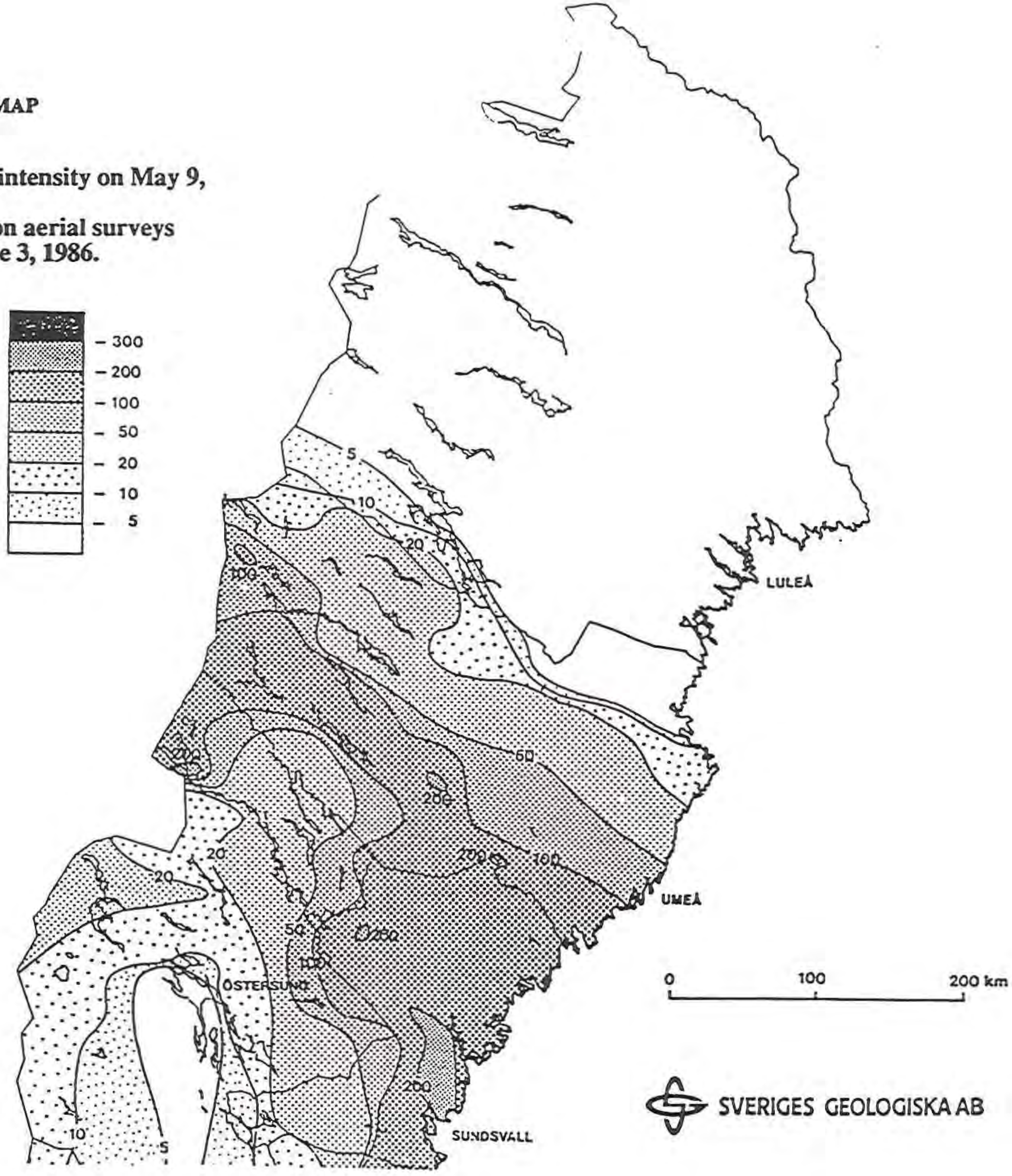


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Fig. 5a

CONTAMINATION MAP

Estimated ground intensity on May 9, 1986, in μR/h.
The map is based on aerial surveys from May 9 to June 3, 1986.

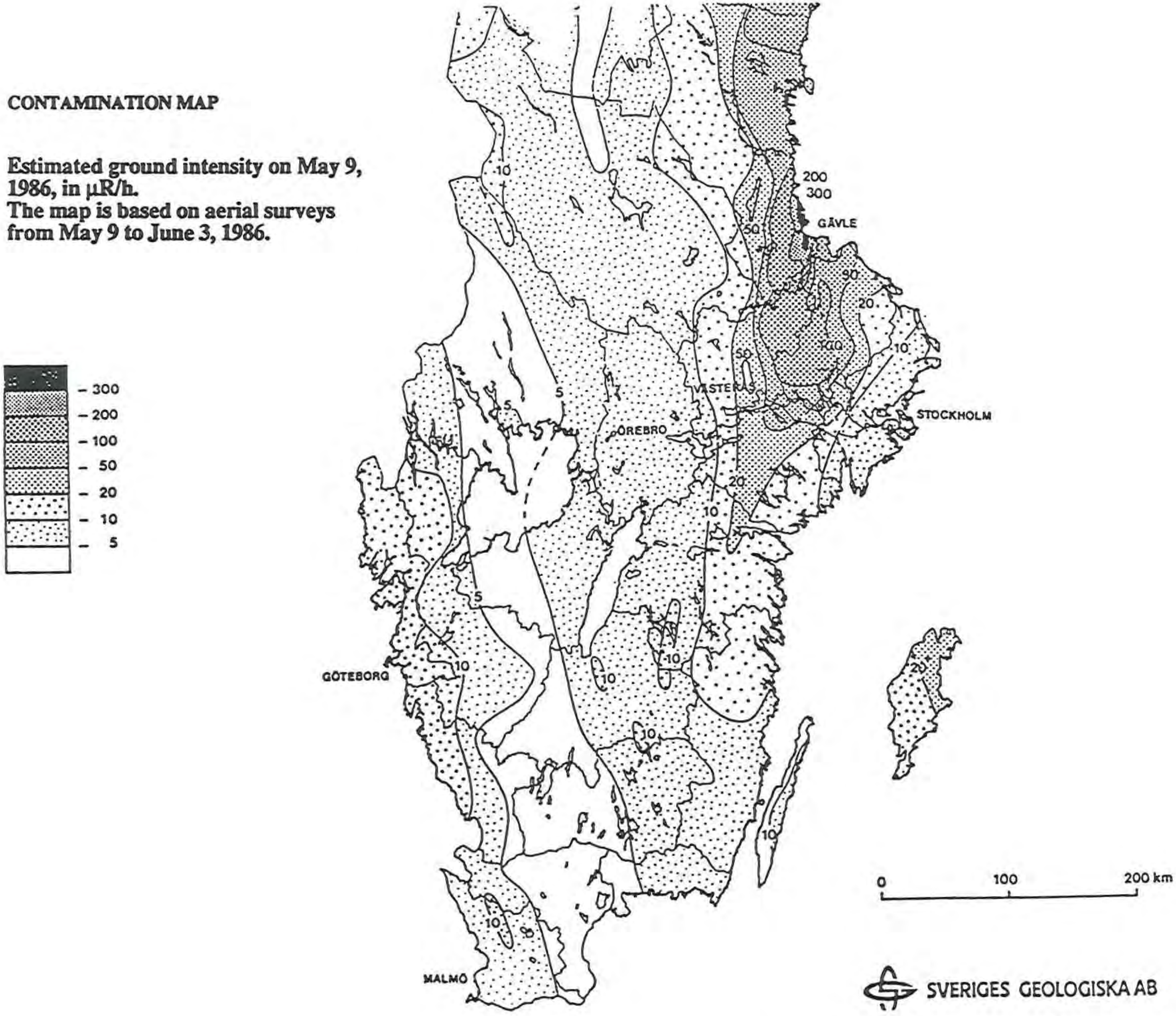


Fig. 5b

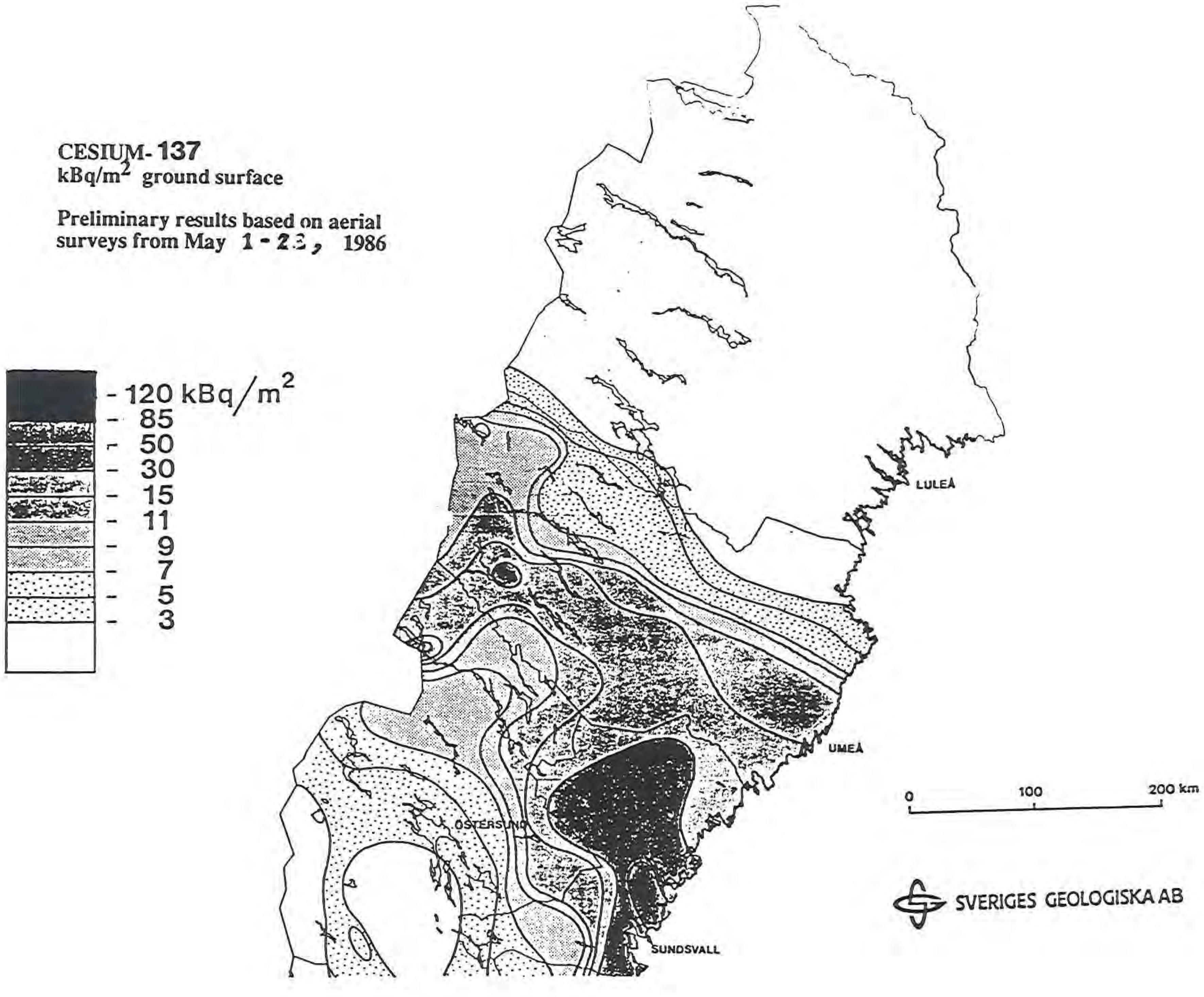
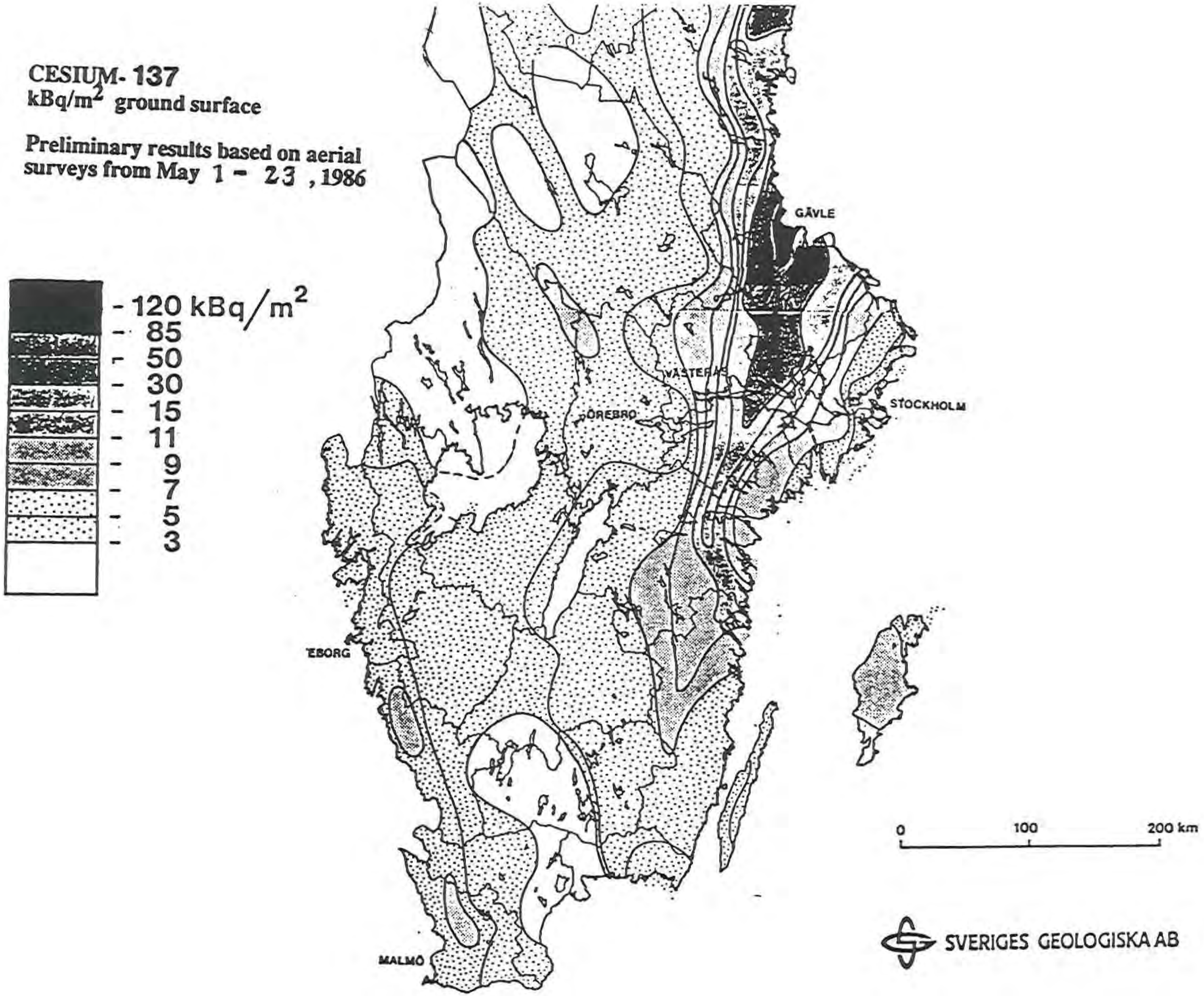

CESIUM-137
kBq/m2 ground surface
Preliminary results based on aerial surveys from May 1 - 23, 1986
- 120 kBq/m2
- 85
- 50
- 30
- 15
- 11
- 9
- 7
- 5
- 3
LULEÅ
UMEÅ
ÖSTERSUND
SUNDSVALL
0
100
200 km
SVERIGES GEOLOGISKA AB

Fig. 6a



CESIUM- 137
kBq/m^2 ground surface

Preliminary results based on aerial surveys from May 1 - 23 , 1986

Fig. 6b

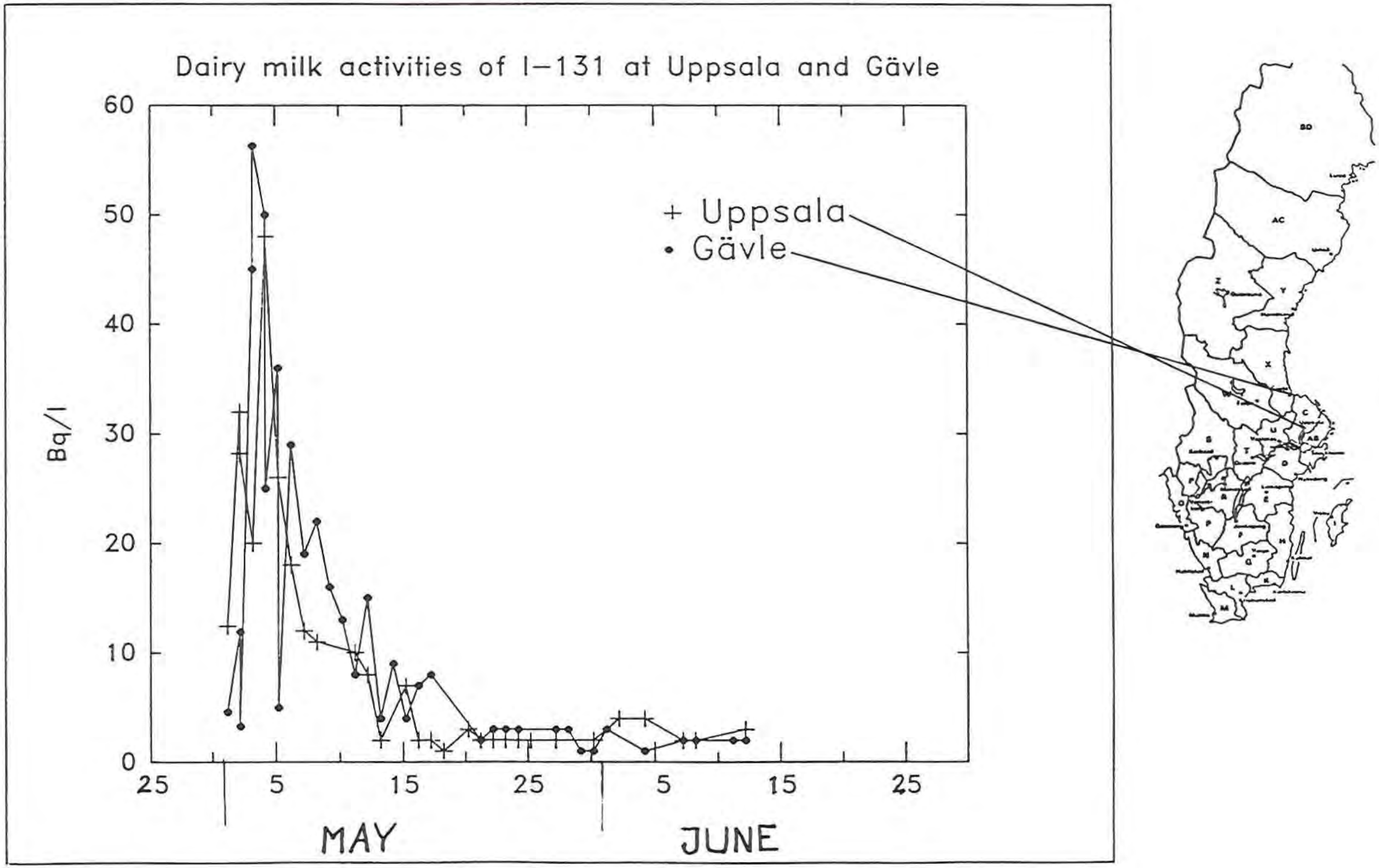

Dairy milk activities of I−131 at Uppsala and Gävle
60
50
40
30
20
10
0
Bq/l
25
5
15
25
5
15
25
MAY
JUNE
+ Uppsala
• Gävle

Fig. 7

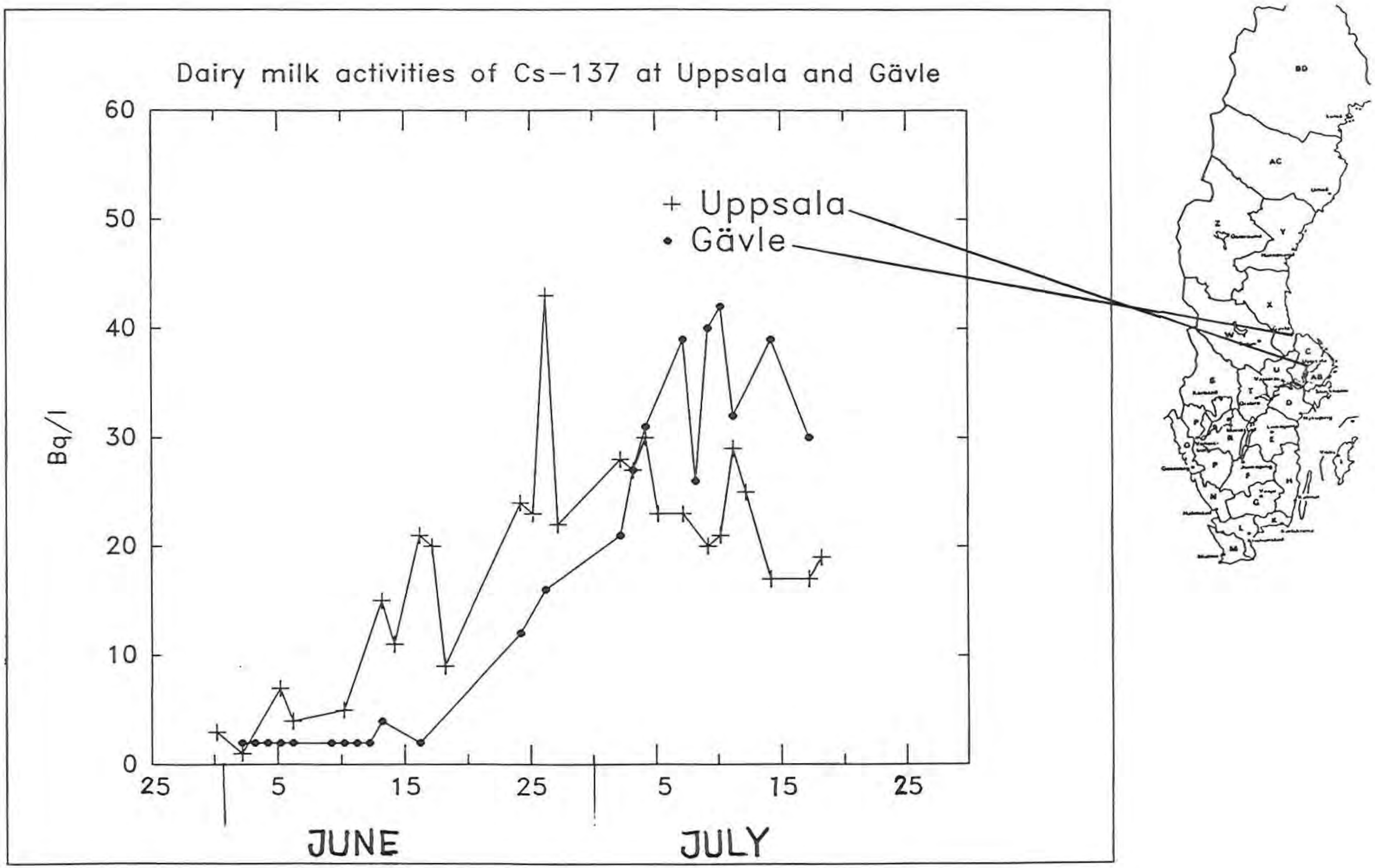

Dairy milk activities of Cs−137 at Uppsala and Gävle
Bq/l
60
50
40
30
20
10
0
25
5
15
25
5
15
25
JUNE
JULY
+ Uppsala
• Gävle
BD
AC
Y
Z
X
W
C
U
AB
S
T
D
E
F
G
H
K
L
M
N
O
P
R

Fig. 8

HITTILLS UTGIVNA SSI-rapport 1986

Rapport-nummer	Titel (undertitel)	Författare
01	Limitation schemes to decrease the radon daughters in indoor air	Gun Astri Swedjemark
02	Radondöttrar och bildskärmsarbete Resultat av en förstudie	Rolf Falk Leif Nyblom
03	Cesium-137 och strontium-90 i mejerimjölk Årsrapport för 1985	Miljölaboratoriet
04	Isotopkommittérapporter 1984	Gunilla Hellström Ingemar Malmström
05	Det falska larmet vid Forsmark den 6 mars 1986	Örjan Hultåker
06	Cesium-137 i strålskyddsinstitutets kontrollgrupp 1985	Gunnar Eklund Rolf Falk
07	Nedfall från Tjernobyl Preliminär rapport	Per-Einar Kjelle
08	Nordisk jämförelsemätning av radioaktivitet i byggnadsmaterial	Hans Möre
09	Kärnkraftindustrins -aktivitetsutsläpp -yrkesexponeringar Fjärde kvartalet 1985	Huvudenhet för kärnenergi
10	Tjernobyl - nedfall, mätningar och konsekvenser	Torkel Bennerstedt Mats Holmberg Lennart Lindborg
11	Persondosmätningar Årsrapport 1985	Albert Kiibus
12	Chernobyl - its impact on Sweden	-

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