SOME GENERAL CONCLUSIONS FROM SIX YEARS OF CHERNOBYL-RELATED RESEARCH IN SWEDEN

Ulf Bäverstam and Leif Moberg

Swedish Radiation Protection Institute
Box 60 204, S-104 01 Stockholm, Sweden

ABSTRACT

A large research programme has been carried through by Swedish scientists as a follow-up of the Chernobyl accident. The long-term behaviour of cesium in the agricultural and aquatic ecosystems shows many similarities with previous experience. This is also true for the reindeer ecosystem. The effects of the cesium fallout on cultivated soils can be substantially decreased by various actions. Large-scale mitigating actions show only minor effects on effective half-times of cesium in fresh-water fish. The contamination of radionuclides in the forest ecosystem is even more difficult to influence. Measurements of resuspension show lower values than earlier findings. Shielding factors for houses generally confirm earlier theoretical estimates. The average radiation doses to people in Sweden are dominated by the external radiation, while the internal doses can potentially be very large and dominate for some individuals. On average the doses after Chernobyl are about the same as those after the nuclear bomb tests.

INTRODUCTION

An extensive research programme has been carried through in Sweden, motivated by the fallout from the nuclear accident in Chernobyl. A major part of this research has been financed and co-ordinated by the Swedish Radiation Protection Institute (SSI). An extensive summary of the results has recently been published (Moberg, ed). Results presented in this article are taken from that book. The programme has encompassed studies of the transport of radioactive elements to Sweden, deposition mechanisms, fallout characterization and deposition measurements. It has been estimated that 5 percent of the released amount of Cs-137 was deposited in Sweden. The deposition was, however, very uneven, with larger areas obtaining a Cs-137 contamination of more than 100 kBq/m^2, and in extreme cases more than 200 kBq/m^2.

Extensive measurements with air-borne detectors, and *in situ* gamma spectrometry allowed the deposition pattern to be determined. This knowledge has then constituted valuable background information for a number of measurements as well as for the action taken by the authorities.

Research in the long time perspective has been focussed on the behaviour and effects of the only long-lived gamma-emitters, Cs-134 and Cs-137, and especially on the transport and accumulation in the terrestrial and aquatic environments, activity measurements on man and dose calculations.

RADIATION DOSES

The average fifty-year dose for individuals in Sweden is about the same as that received as a consequence of the atmospheric bomb tests. The variation in doses between individuals is, however, much larger after Chernobyl,

due both to the non-uniform deposition and to the large variation in intake. The resulting total effective dose commitment to man in Sweden is summarized in this table.

Collective dose (manSv)		Individual dose (mSv)	
External	Internal	External (ratio max/min)	Internal
5000	1000	0.6 (50-100)	0.1 (10^3-10^4)

Of special interest are groups living in high-deposition areas with diets including large amounts of game meat, reindeer and freshwater fish, for example reindeer-breeding Sami families. Whole-body measurements show that individuals from this group receive average internal doses 100 times that of the average Swede. On the other hand, people who buy their food and live in low-deposition areas receive a dose equal to one tenth of the average value.

The external dose follows more closely the deposition pattern and constitutes the larger part of the collective dose commitment after Chernobyl, in average five times larger than the dose commitment from intake.

TERRESTRIAL RADIOECOLOGY

The high levels of cesium concentration in lichens, the predominant fodder for reindeer during the winter season, subsequent to fallout are well known since the sixties. This time, however, the maximum values were more than ten times higher than after the bomb tests. The effective half-time of Cs-137 in lichen was found to be 8-14 years during the sixties and recently repeated measurements on residual bomb-cesium give values of 8-10 years. Even if the time elapsed since the Chernobyl accident is short, preliminary results indicate half-times in the range 6-15 years, i.e. similar to earlier experience. A number of actions have been taken to decrease the consequences. Moving reindeer to areas with lower deposition, use of bentonite to decrease uptake in the reindeer, adding cesium-free food to the diet prior to slaughter, and the use of zeolites are methods that have been tested with varying degrees of success.

In spite of these actions a large number of slaughtered reindeer have been discarded for selling in the open market. For reindeer in some areas the long half-time of cesium in lichen will be a problem for some decades.

Studies of the radioactive contamination of the forest ecosystem in Sweden were limited during and after the sixties. Results from post-Chernobyl observations of the amount of Cs-137 remaining in different parts of the boreal ecosystem, the fraction lost by run-off, the concentration prevailing in plants in important food-chains and concentrations in moose indicate that changes in levels about one-year after the initial deposition will be exceptionally slow. In fact, it will probably be governed by the physical decay of the radioactive cesium. One concequence of this is that

the collective dose from forest products might be of the same order as that from agricultural products. However, this will be clarified by further studies. The concentrations of cesium in moose and roedeer, in particular, are also high. The variations between individual animals, years etc are large.

Radioecological questions related to agriculture have been studied right from the end of the fifties. A basis of knowledge existed prior to the Chernobyl accident. However, even though the pre-Chernobyl studies were in progress over a long period, the aims were restricted. The studies after Chernobyl have opened up a wider scope. On a large number of sites the cesium transfer both to grass and grain crops has been measured. The results have increased the experience on the effect of soil composition on cesium transfer to crops, on the importance of the nuclide depth distribution and variations due to differences in the agricultural systems used. Results from experiments with different levels of potassium fertilization are generally in agrement with earlier findings. Transfer coefficients of radioactive cesium to cow's milk show a large range of values, but are similar to those which were generally accepted before the accident.

AQUATIC RADIOECOLOGY

A number of radionuclides originating from the accident were detected in the marine biota of the Baltic Sea. The only ones frequently observed in fish were Cs-134 and Cs-137. A major fraction of the total load of Cs-137 to the Baltic Sea was transferred to the sediments already during the first year. The accumulation of cesium in fish in the Baltic Sea is much smaller than in freshwater fish, and the radiological concequences from the contamination of the Baltic Sea were quite small.

In lake ecosystems a rapid incorporation of Cs-137 resulted in high concentrations. Organisms at lower trophic levels reached their maximal activity concentrations already during 1986. The predator fish reached maximum values the following years, the exact time depending on the type of lake and species. A major part of the Cs-input was relatively early deposited on the bottom sediments. Resuspension of cesium from the sediments has been found to be an important reason for delayed recovery in some lakes. Fish that consume macro invertebrates which feed on the contaminated sediment layer can cause sustained accumulation of cesium. In particular, this has been demonstrated in oligotrophic high-altitude lakes.

The apparent half-time of cesium in fish varies considerably (0.6-13 years) depending on the type of lake, species, age of the fish etc. However, the half-times for large perch and large pike seem to be similar to those found during the sixties.

It is known that the content of stable potassium in the water is negatively correlated to the concentration of Cs-137 in fish but potash treatment of lakes after the deposition does not seem to be a very effective way to speed up recovery. The treatment performed in oligotrophic lakes imply that the recovery can never be more than 5% faster compared with no treatment. This result is supported also by recent Swedish laboratory experiments on Chernobyl contaminated fish and water. Once the lake is contaminated with cesium, a subsequent addition of potassium has little effect on the half-time. Liming of lakes shows the same negative results.

MODEL TESTING

The Chernobyl databases have been utilized to test environmental transfer models primarily within the international BIOMOVS study. Two main cases, based on lake and vegetation-milk data, were investigated. The accuracy of the predictions for water and sediment was found to be satisfactory for most radioecological assessments. The discrepancies were higher for fish. For the milk pathway about half of the predicted time-integrated concentrations of I-131 and Cs-137 in vegetation were within a factor of two from the observed values, while for the time-integrated predictions of I-131 and Cs-137 in milk the discrepancies were higher.

The available data sets, prolonged in time, will be available for future model testing and analyses.

THE FALLOUT

As a result of the relatively high deposition in some parts of Sweden it has been possible to perform field measurements of a number of parameters (dry and wet deposition velocities, resuspension, shielding factors for houses) which earlier had to be estimated from small-scale experiments or measured in environments different from those in Sweden. The measured shielding factors for houses confirm earlier theoretical estimates based on experiments. Measurements of resuspension show lower values than those often used prior to the Chernobyl accident.

GENERAL CONCLUSIONS

It would appear that many of the results and many conclusions after Chernobyl support corresponding earlier data. The very slow recovery in the forest ecosystem had not previously been fully appreciated.

The average doses in Sweden are low, and comparable to the doses obtained from the atmospheric testing of nuclear weapons. However, the variation in doses between individuals is much larger after Chernobyl. It is important that the deposition took place before the growing season, and that the major farming areas of Sweden received a very low contamination which contributed to the fact that there were such low doses from agricultural products.

The results are very similar to those from the sixties. There is, however, an important difference between the research in the eighties and that in the sixties. Today a more ecological approach is encountered. This fact, which at least in part is explained by the larger number of scientists trained in ecology and taking part in radioecological research, contributes to the fact that the present-day results have a higher credibility than those of former years.

REFERENCE

The Chernobyl fallout in Sweden. Results from a research programme on environmental radiology. L Moberg (Ed.), pp 633. Available from the Swedish Radiation Protection Institute, Box 60 204, S-104 01 Stockholm, Sweden