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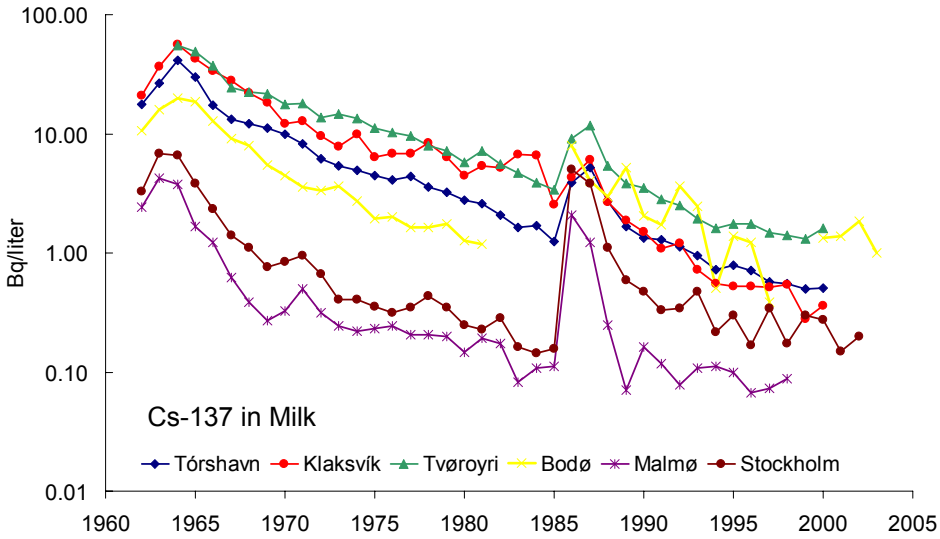
Modelling integrated transfer of ^{137}Cs to cows milk in the Faroe Islands, Norway and Sweden

Hans Pauli Joensen



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Modelling integrated transfer of ^{137}Cs to cows milk in the Faroe Islands, Norway and Sweden.

Report for the NKS EcoDoses project, October 2004.

Hans Pauli Joensen, Faculty of Science and Technology, University of the Faroe Islands.

Introduction

The terrestrial environments in Norway, Sweden and the Faroe Islands have received radioactive debris from the nuclear weapons tests and from the Chernobyl accident 26 April 1986. This study uses the UNSCEAR model to estimate the integrated transfer coefficients of ^{137}Cs from wet deposition to cows milk from selected sites in the three countries. The model relates the concentration of a radionuclide in a sample from a given year to the deposition rate of the radionuclide from precipitation in the given year and in the year before, and to the accumulated deposition from previous years.

Material

The data for the study cover ^{137}Cs activity concentration in cow milk (Bq/liter) from Bodø in Norway, Malmö and Stockholm in Sweden, and from Klaksvík, Tórshavn and Tvøroyri in the Faroe Islands (respectively in the north, middle and south of the Faroe Islands). Observations of wet depositions (Bq/m^2) were available from the sites in Norway and the Faroe Islands. Wet deposition data from Risø in Denmark were used as representative for Malmö. No deposition data series were available for Stockholm. The observations are presented in Figs. 1 and 2.

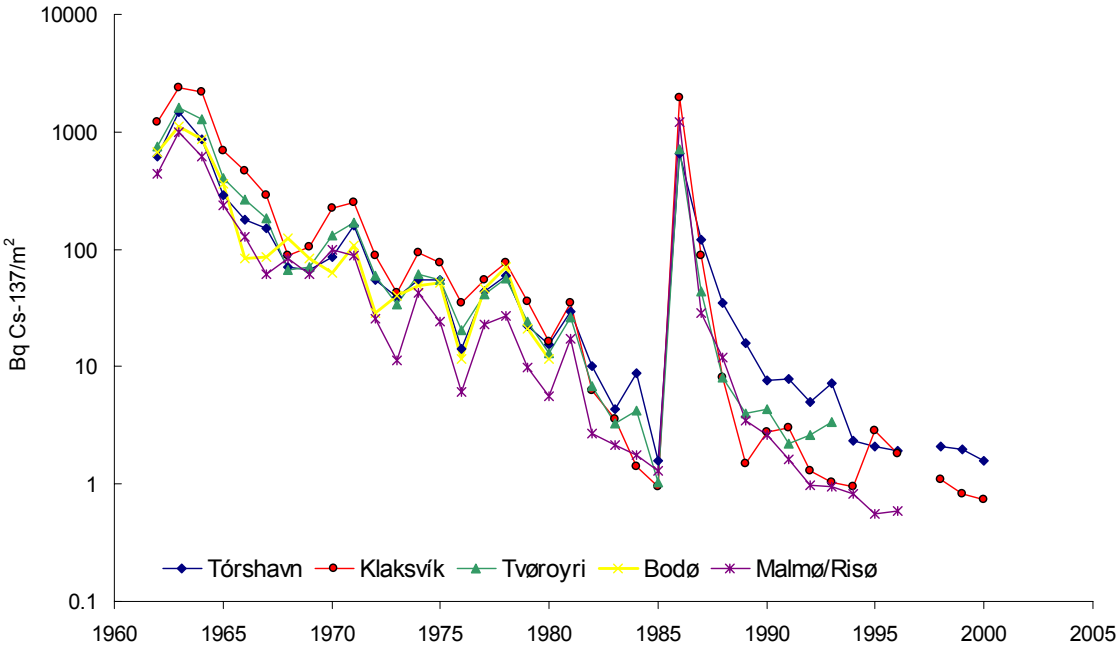

Figure 1. Annual ^{137}Cs deposition at the sites. Observations at Risø in Denmark have been used to represent Malmö in Sweden.

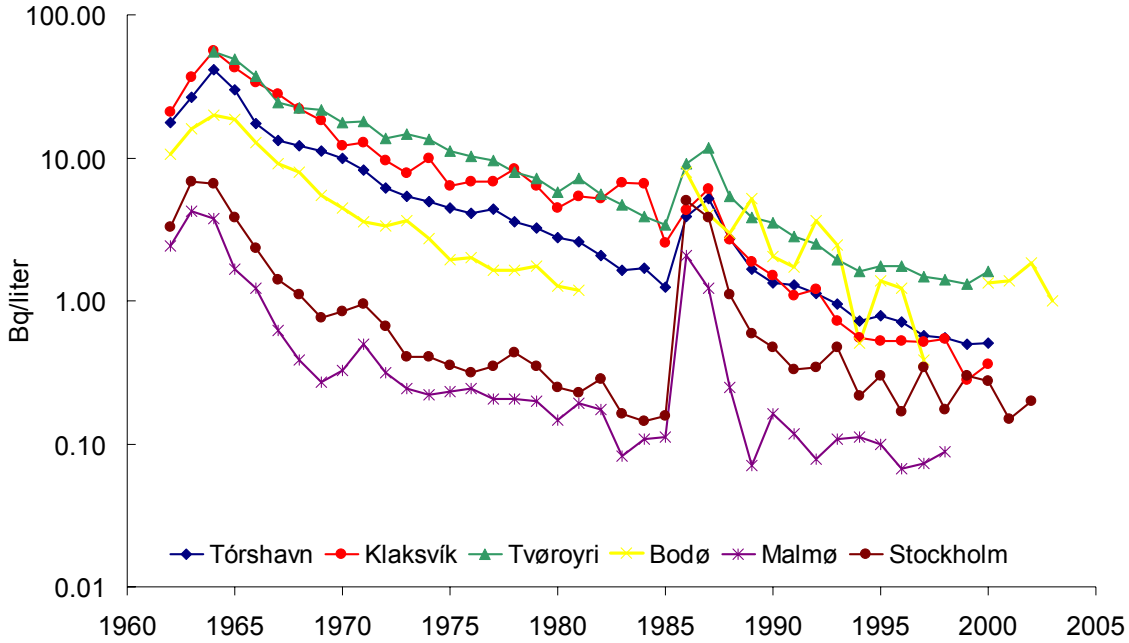

Figure 2. Cs-137 activity in cows milk from the sites. Stockholm have been included for comparisons, although no deposition data were available from Stockholm.

Milk data from Klaksvík and Tvøroyri derive from samples from local producers, while data from Tórshavn derive from a dairy collecting milk across the country. The milk samples from Bodø and Malmö are dairy samples.

Maximum deposition values were observed in 1963 at all the selected sites. The ^{137}Cs deposition levels in 1986 were similar to the values in the early 1960's, but the early decrease was faster after the Chernobyl accident. This should be related to the fact that fallout from the Chernobyl accident came from an explosion of a nuclear reactor while the nuclear weapons fallout derives from tests carried out in a period of several years. No deposition data were available from Bodø after 1980.

The ^{137}Cs activity concentration in milk follows the same general trend with time as the ^{137}Cs deposition. The ^{137}Cs activity in milk from Klaksvík does, however, not reflect the signal in wet deposition in Klaksvík after the Chernobyl accident. This may partly be due to a different feeding practice of the cows in Klaksvík just after the Chernobyl accident, but a more complete explanation remains to be found.

The highest ^{137}Cs activity concentration in milk is found at the Faroese sites, while the lowest concentrations are found at the Swedish sites. The concentration was at maximum in 1964 at all sites, with the fastest early decrease in Sweden. The largest impact from the Chernobyl accident was observed in Swedish milk, with lower concentrations in Malmö as compared to Stockholm, and with an increased difference between the two Swedish sites after 1986. The maximum concentrations in milk after the Chernobyl accident occurred in 1987 in the Faroe Islands and in 1986 in Norway and Sweden.

Method

The relation between radioactivity in a sample and fallout rates is modelled as follows (UNSCEAR, 1977; Aarkrog, 1979; AMAP, 1998):

$$C_i = b_1 \cdot d_i + b_2 \cdot d_{i-1} + b_3 \cdot \sum_{k=1}^{k=\infty} d_{i-k} \cdot e^{-\lambda \cdot k} \qquad (1)$$

The index i corresponds to a given year, C_i is the concentration of a radionuclide in a sample from year i, d_i is the observed fallout rate (kBq/m^2) in year i, λ is the decay constant $\lambda = \ln(2)/T$, and T is an estimated effective halflife of the considered radionuclide, as determined from the multi-regression analyses between concurrent observations of wet deposition and activity concentration in milk. The summation is carried out over the deposition of all preceding years, each weighted by an exponential term describing the combined physical decay of the radionuclide and any decrease in the availability to the foodstuff.

The model-based estimate of the integrated transfer coefficient (ITC) of a radionuclide from fallout to foodstuff is given by:

$$ITC = b_1 + b_2 + b_3 \cdot e^{-\lambda} (1-e^{-\lambda}) \qquad (2)$$

Results

The results are presented in Table 1 and Figs. 3-7, showing fairly good correlation between observations and model. As seen from Figs. 3-7, the model generally overestimates the activity concentration in milk after 1985. The results express a geographical variation of the ITC's, also within the Faroe Islands, although the country has a total geographical extent of only 1399 km^2. The highest and lowest ITC's are found in Tvøroyri and Malmö, respectively. The value in Tvøroyri is one order of magnitude higher than the value from Malmö. The estimated effective radioecological halflife of ^{137}Cs is shortest in Bodø (2.0 years) and longest in Malmö (17 years). It should be noted that wet deposition at Risø in Denmark was used in the model for Malmö, and this may affect the estimates found for Malmö.

Table 1. Model-calculated integrated transfer coefficients (ITC). T is the estimated effective ecological half-life in years. The coefficients in the model are given by b_1, b_2 and b_3. R^2 is the square regression coefficient. p-values are given in brackets for the b_1, b_2 and b_3.

	b_1	b_2	b_3	T Years	R^2	ITC (Bq/l)y per kBq/m^2
Tvøroyri	0.00829 (0.04)	0.02101 (<0.0001)	0.00546 (<0.0001)	4.5	0.992	62.1
Tórshavn	0.00944 (<0.0001)	0.01889 (<0.0001)	0.00359 (<0.0001)	3.5	0.989	44.7
Klaksvík	0.00829 (<0.0001)	0.01010 (<0.0001)	0.00383 (<0.0001)	3.0	0.983	33.1
Bodø	0.00694 (<0.0001)	0.00719 (<0.0001)	0.00422 (<0.0001)	2.0	0.991	24.3
Malmö	0.00396 (<0.0001)	0.00120 (<0.0001)	$3.77 \cdot 10^{-5}$ (0.02)	17	0.989	6.07

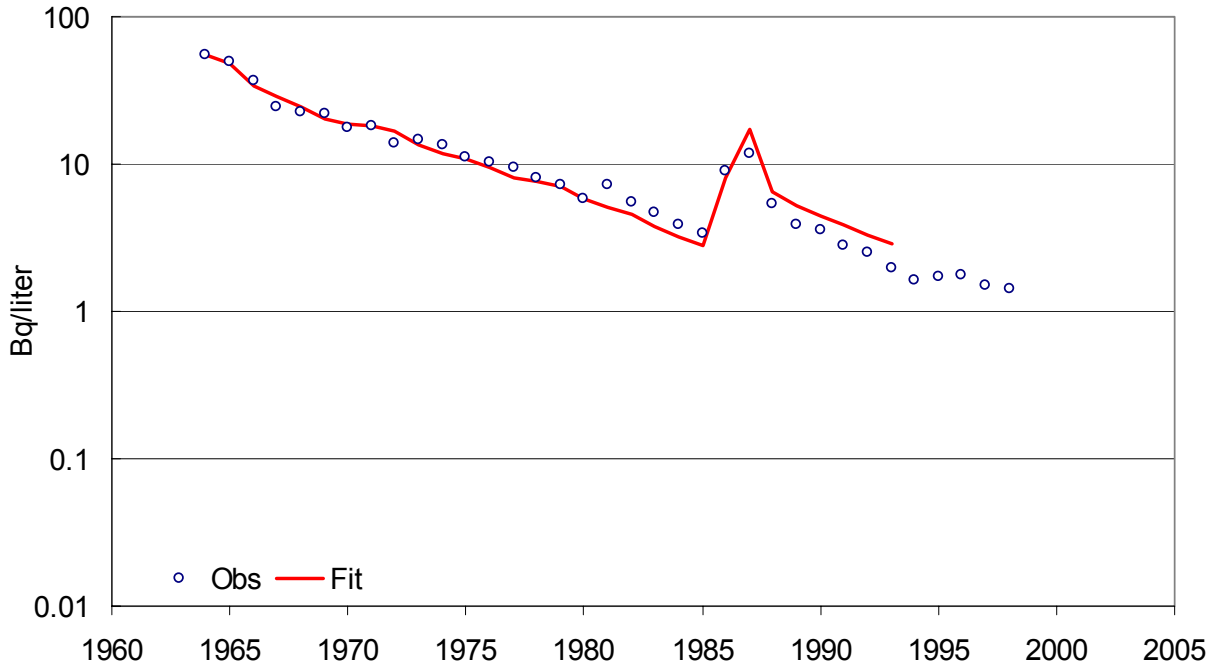

Figure 3. Cs-137 in milk from Tvøroyri. Observations and model results.

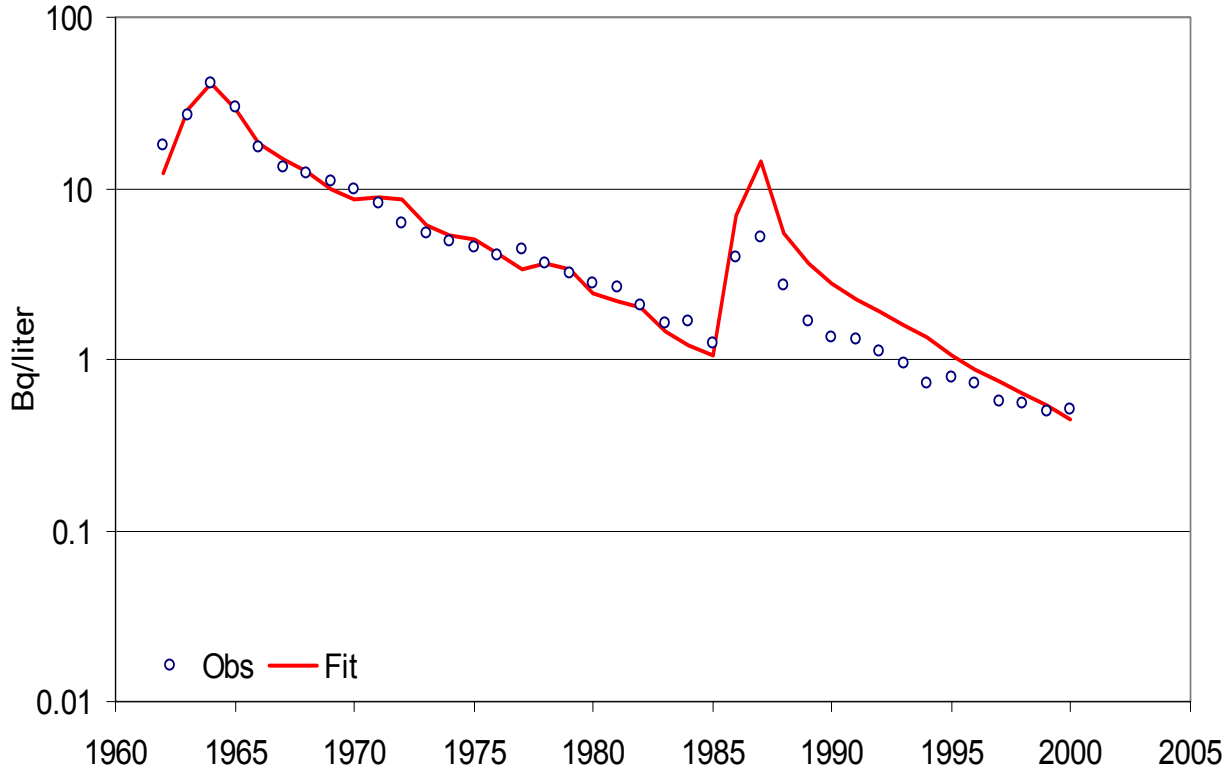

Figure 4. Cs-137 in milk from Tórshavn. Observations and model results.

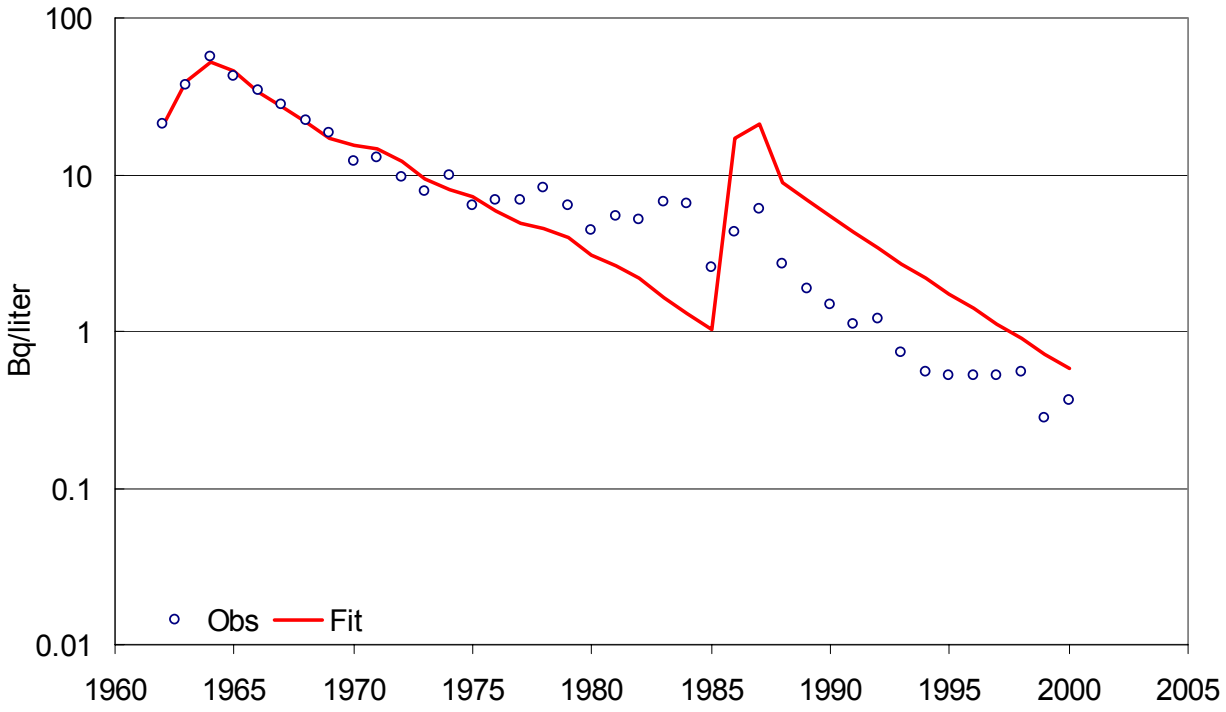

Figure 5. Cs-137 in milk from Klaksvík. Observations and model results.

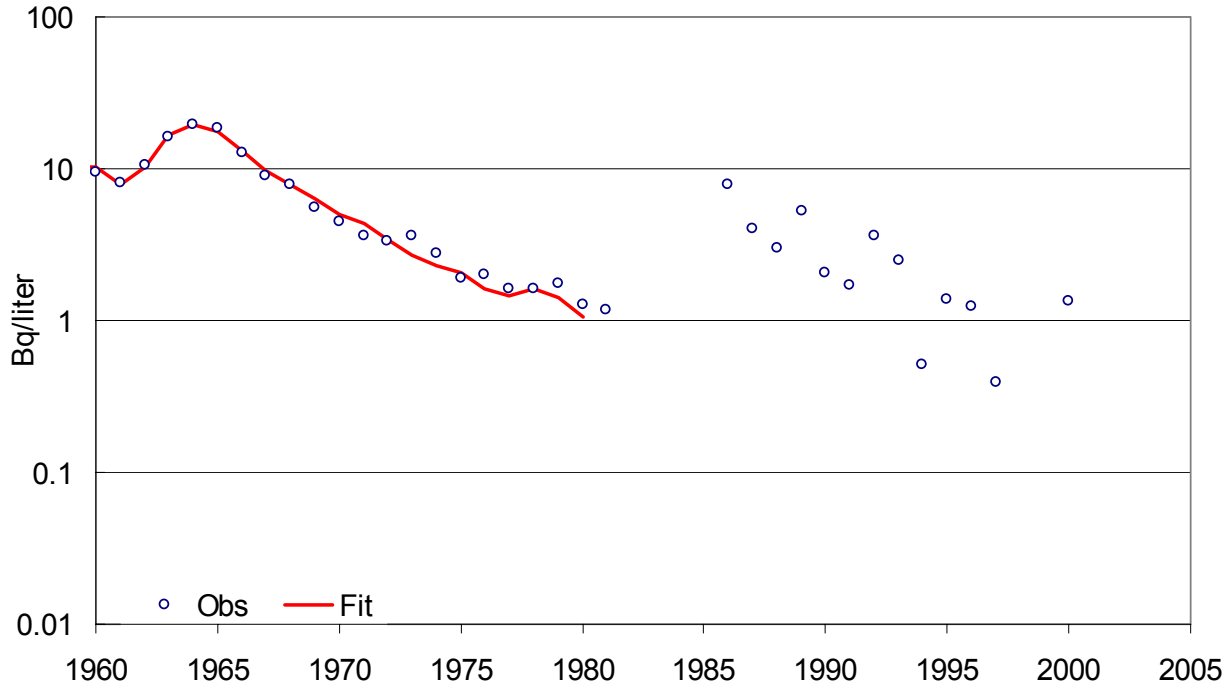

Figure 6. Cs-137 in milk from Bodø. Observations and model results. No deposition data were available from Bodø after 1980.

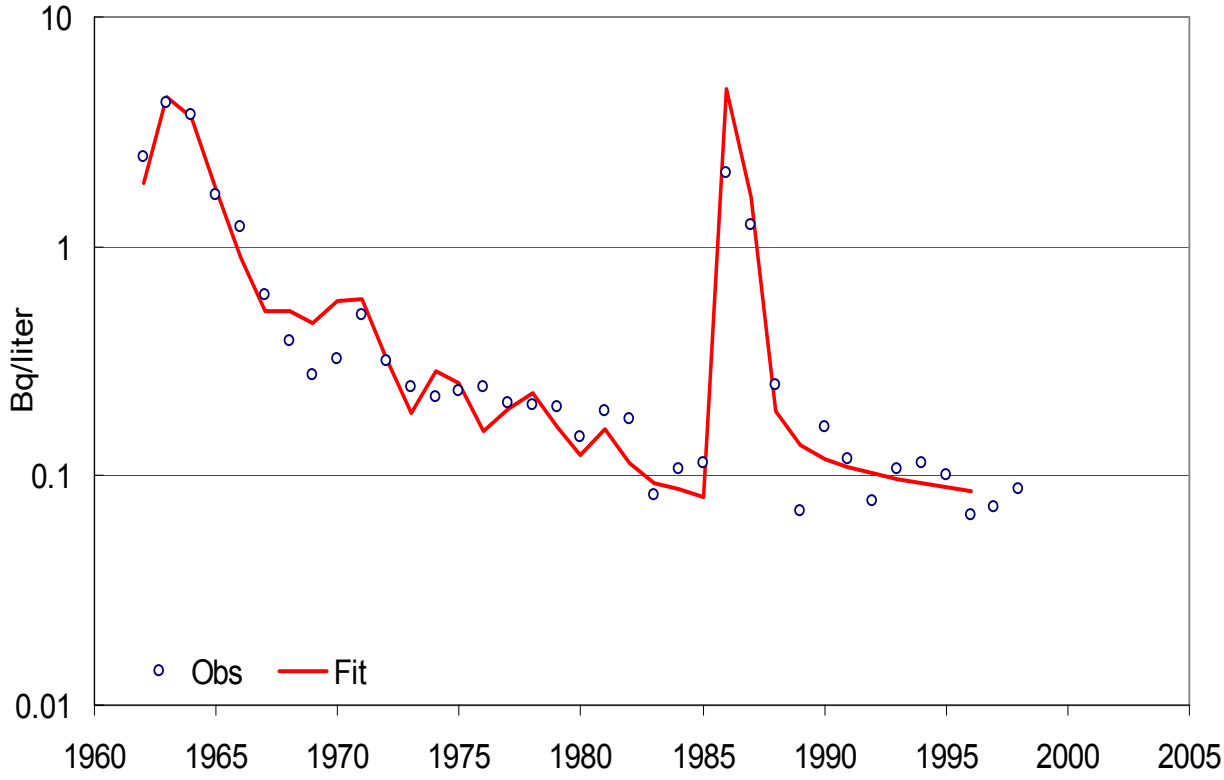

Figure 7. Cs-137 in milk from Malmö. Observations and model results.

Conclusions

The integrated transfer coefficients are found to be higher at the Faroese sites than at the Norwegian and Swedish sites, indicating relatively high individual doses from ingestion of milk in the Faroe Islands.

The integrated transfer coefficients of ^{137}Cs to cow milk in the Faroe Islands are also high compared to other countries. UNSCEAR, 1977, reports ITC for cow milk in different countries around the world, using the unit $Bq(gK)^{-1}y$ per $kBq \cdot m^{-2}$. UNSCEAR reports the highest value of 27.51 for the Faroe Islands followed by 15.48 for Norway. The lowest value of 3.23 was reported for Denmark.

The ITC's are found to vary also within small geographical areas. They vary with a factor of two between the Faroese sites. The reason for this may partly be due to differences in the soil characteristics at the localities. This could, however, not be tested in the present study because of lack of data.

Acknowledgements

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