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THE USE OF CHERNOBYL FALLOUT DATA TO TEST MODEL PREDICTIONS OF THE TRANSFER OF ^{131}I AND ^{137}Cs FROM THE ATMOSPHERE THROUGH AGRICULTURAL FOOD CHAINS

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ABSTRACT

This paper highlights the results of a recent international model validation study (BIOMOVS/A4) that has collected data during the aftermath of the Chernobyl accident from 13 sites around the Northern Hemisphere. Models commonly used in the U.S.A. for regulatory assessments tended to overpredict by amounts that often approached and/or exceeded a factor of ten. Large overestimation was usually the result of compound conservatism employed in a model at numerous stages. In some cases, seemingly accurate predictions were the result of compensatory error. The study also revealed that similar models produced different results when operated by different users, and that accuracy was affected more frequently by the choice of parameter values than by differences in structural complexity.

INTRODUCTION

Decisions about measures to prevent or reduce exposures from releases of radioactivity are often based on the predictions of mathematical models. In 1985, an international model validation study (BIOMOVS) was initiated by the Swedish National Institute for Radiation Protection to test the accuracy of mathematical models used to predict the transfer of radionuclides and other potentially hazardous trace substances in the biosphere.[1] Phase I of this study concluded in October 1990 in Stockholm, Sweden. Of the numerous test scenarios that comprised the BIOMOVS study, one, the A4, obtained information on radioactive fallout from the Chernobyl accident to test model predictions of the fate of radionuclides in agricultural food chains.[2]

Data were gathered on ^{131}I and ^{137}Cs in Chernobyl fallout for air, rain, vegetation, milk and meat from 13 sites located throughout the Northern Hemisphere. To ensure the process of blind testing, participants were initially given information about the daily concentrations in air (including the physicochemical state of ^{131}I), the daily amount of precipitation and the prevailing conditions of agricultural management. The identity of the sites and the measured concentrations in the test endpoints were kept secret until after model predictions were submitted.

More than 20 models were included in this study. Six of these were from the U.S.A., of which 4 were developed for regulatory assessment of routine releases. This paper mainly shows the results for the U.S. models; however, details of the complete BIOMOVS/A4 study can be obtained either from the Swedish National Institute for Radiation Protection or from H. Köhler, International Atomic Energy Agency, Vienna, Austria.[2]

RESULTS

The various sites from which test data were obtained differed in climate, agricultural practices, the time of arrival of the plume, and in the magnitude of time-integrated air concentrations of ^{131}I and ^{137}Cs. Despite these differences, the ratios of the time-integrated concentrations in milk, meat, and vegetation to the time-integrated concentration in air generally varied by less than one order of magnitude.

Larger variations mainly occurred where grazing bans effectively reduced time-integrated concentrations of ^{131}I in milk. Grazing bans were not as effective in reducing the time-integrated concentrations of ^{137}Cs as they were for ^{131}I (Fig. 1).

For ^{137}Cs, factors affecting differences in the ratios of time-integrated concentrations were the occurrence of wet deposition and feeding of stored contaminated feed. Wet deposition resulted in an increased amount of ^{137}Cs on vegetation as compared with dry deposition.

By contrast, vegetation concentrations of ^{131}I were either not affected by wet deposition or were masked by an equally high amount of dry deposition. During periods of wet deposition, ^{137}Cs in rain appeared to be more readily retained by vegetation than was ^{131}I.

Analysis of time-integrated concentrations permits comparison of steady state models designed for the prediction of concentrations from long-term, averaged release rates and dynamic models designed to predict time-dependent concentrations from time-varying releases.[3]

The predicted-to-observed ratios (P/O) for time-integrated concentrations in milk and meat reflect the cumulative outcome of all processes affecting the transfer of radionuclides from the atmosphere to forage and from forage to animal produce (Figs. 2 and 3). Comparison of predictions against intermediate measurements such as concentrations in rain and forage revealed that seemingly accurate predictions were often the result of compensatory error. Large over- or underprediction was frequently the result of compound bias introduced within several steps in the model of the agricultural food chain.

A tendency towards large overprediction was evident among U.S. models developed for regulatory purposes. This tendency was predominantly affected by the use of conservative pre-Chernobyl values for milk and meat transfer coefficients and the misapplication of these models at locations where grazing bans were in effect. The tendency to overpredict was also the result of the common modelling assumption that 20 to 25% of the amount of ^{131}I and ^{137}Cs deposited in rain is initially retained by pasture vegetation.

Other factors influencing the results were assumptions about the chemical form of ^{131}I in air and the values assumed for the parameters describing precipitation scavenging, wet and dry deposition, and weathering from vegetation.

In most cases, assumptions about parameter values were more influential in determining the accuracy of predictions than were assumptions about model structure. Exceptions to this trend was with the prediction of milk concentrations during the time of grazing bans when animals were kept indoors. At these times, it was important that models accounted for inhalation of indoor air and the ingestion of indoor deposits.

The importance of the user in determining the accuracy of model predictions was also revealed. Large differences in results were produced by nearly identical models employing similar, if not identical, parameter values but run by different individuals. These differences were caused by interpretation of the initial conditions described for each site.

DISCUSSION

The A-4 Scenario of BIOMOVS has been the largest model validation exercise performed to date on models concerned with the transfer of radionuclides in agricultural food chains. In general, the study has shown that the transfer of ^{131}I and ^{137}Cs from rain to forage and from forage to milk and beef is typically lower than assumed by most models developed prior to 1986. Those models that used generic parameter values commonly assumed prior to the Chernobyl event generally overpredicted the concentrations of ^{131}I and ^{137}Cs in milk and meat. An exception to this conclusion occurred when errors were compensatory.

The presence of compensatory errors demonstrates the need for measurements on as many state variables as possible when acquiring data for model testing. Failure to do so can lead to unwarranted confidence.

Concern has been expressed about the general applicability of the results of this validation exercise. Some of the BIOMOVS participants have already made changes to their models based on knowledge gained from the A4 Scenario. Others have expressed satisfaction that their models were conservatively biased. Supplemental studies are now beginning to indicate, with the exception of regions near the Chernobyl reactor in the U.S.S.R., that the agricultural behavior of Chernobyl fallout is probably not unique to the Chernobyl event.[4]

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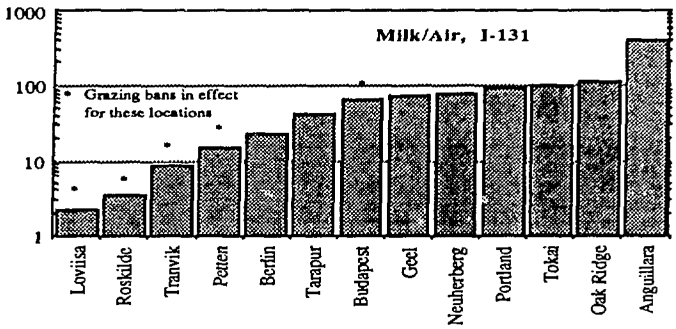

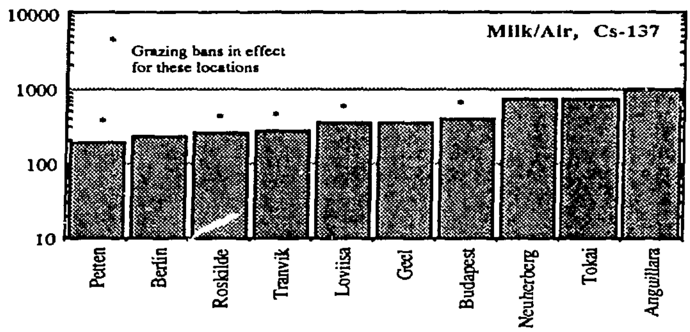

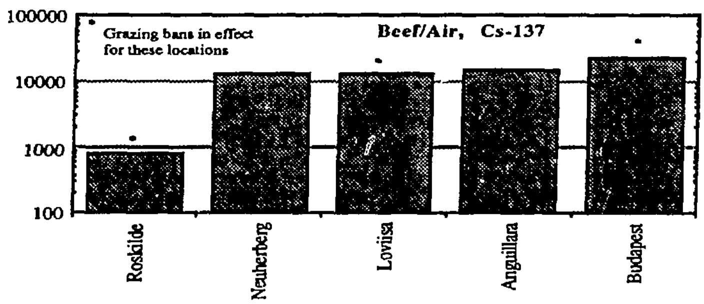

Figure 1. Concentration ratios of observed time-integrated concentrations in milk and beef to that in air (m^3/kg) for ^{131}I and ^{137}Cs

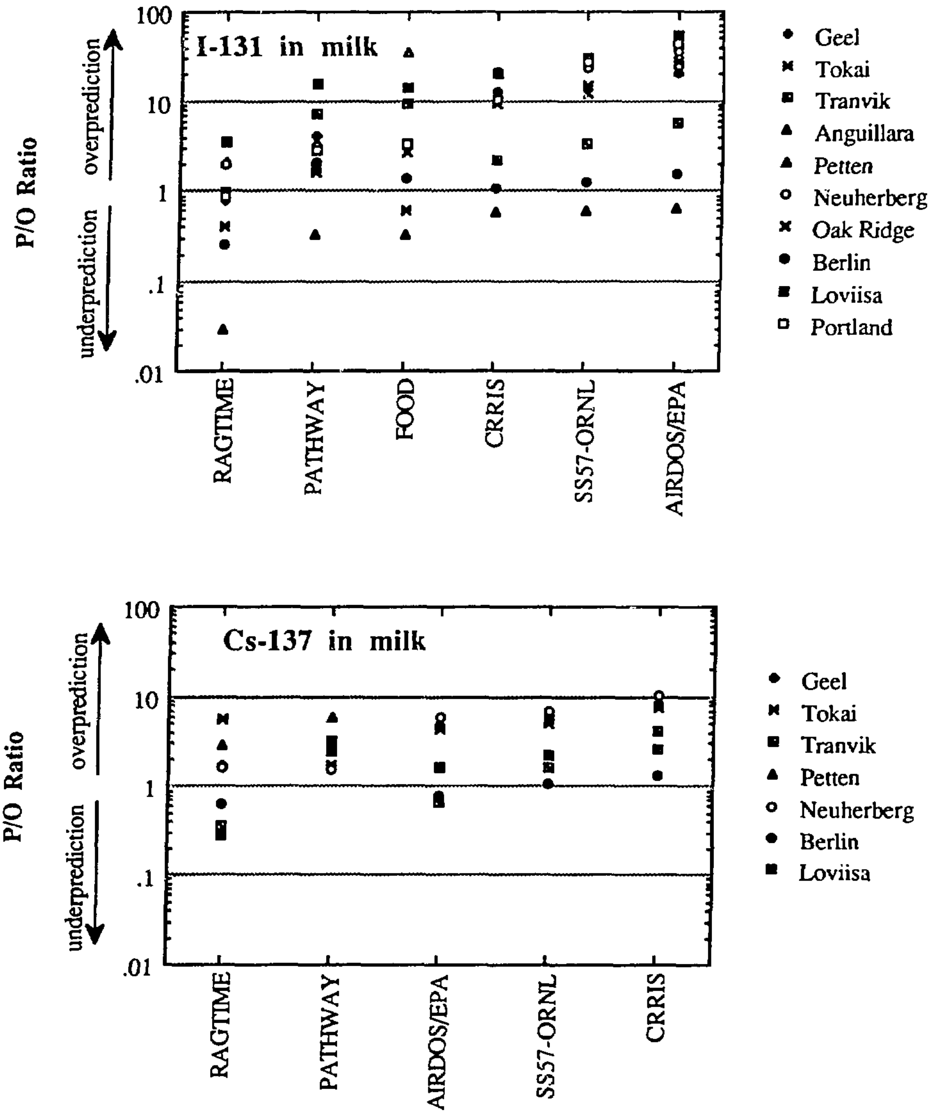

Figure 2. Predicted to observed ratios for time-integrated concentıations in milk.

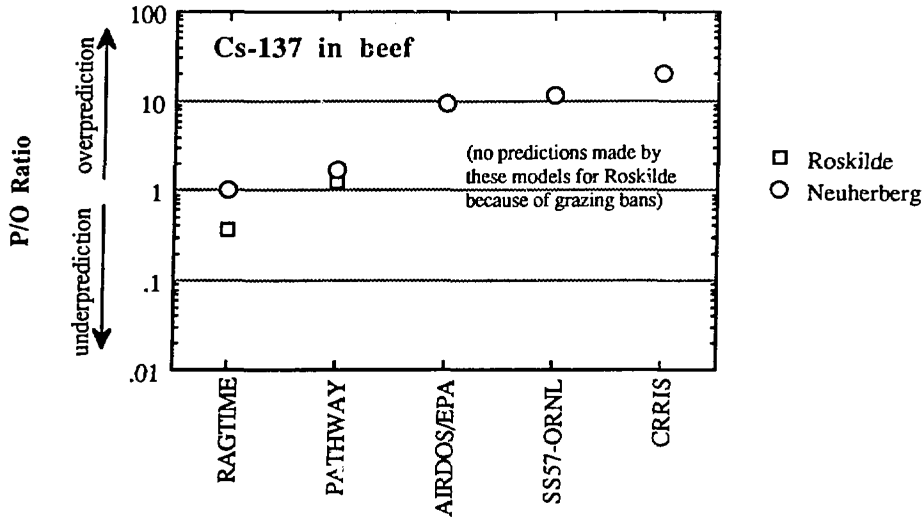

Figure 3. Predicted to observed ratios for time-integrated concentrations in beef.