CONCEPT AND VALIDATION STUDIES OF THE REAL-TIME REACTOR-ACCIDENT CONSEQUENCES ASSESSMENT MODEL "ECOSYS"

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ABSTRACT

The Chernobyl accident has demonstrated the urgent need for computer programs for real-time assessment of potential radiological consequences of major reactor accidents and for timely recommendations of useful and cost-efficient countermeasures. During the past decade the dynamic radioecological program "ECOSYS" has been developed by us for nuclear accident consequence assessment with high resolution in space, time and exposure pathways. The Chernobyl reactor accident leading to relatively high contamination of Southern Germany provided excellent conditions for realistic validation studies of concept, sub-models and parameters of ECOSYS. More than 10 000 low level and in-situ gamma spectroscopy measurements were performed to study the behaviour of radionuclides in food chains and in the urban environment and to compare the results to theoretical predictions of ECOSYS. The results show good agreement in the contamination levels of important food stuffs and in external exposure dose rates from a given surface contamination. Improvements were necessary in the assumptions regarding the food consumption habits - which changed considerably - and in the functions describing the weathering off from urban and plant surfaces. Some results of this validation study and the concept of the improved computerized model, which is being converted into a real-time code, are discussed in this paper.

INTRODUCTION

For the last ten years we have been developing a detailed time-dependent radioecological model (ECOSYS) for the realistic assessment of present and the prediction of future exposures of members of the public after major accidental releases of radionuclides to the atmosphere from nuclear facilities. This model has been and is being used in generic probabilistic risk assessment studies for reprocessing plants, deep underground waste storage sites, and for nuclear power plants. The reactor accident of Chernobyl forced us to use this model for the first time in a given actual situation of large scale environmental contamination (initially around 0.5 MBq/m² in Bavaria (1)) for dose assessment and analysis of the efficiency of mitigating countermeasures. On the other hand this situation gave us also the unique possibility to test the validity of the predictions of this model. More than 10 000 laboratory and in situ gamma spectroscopy measurements have been performed since May 86 for this purpose. This paper reports some of our experiences made in this validation study and draws some conclusions as to the design of adequate real time reactor accident consequences assessment programs; further results can be found in ref. (2-8).

THE ECOSYS MODEL

ECOSYS is a time-dependent radioecological model for the prognostic assessment of radiation exposures of members of the public after accidental releases of radionuclides into the atmosphere. It takes into account external radiation from a passing cloud and from deposited radionuclides (including shielding by houses) and internal exposure from inhalation and ingestion. The food chain is modelled in great detail in temporal aspects (considering time in the year as well as time after the accident) and taking into consideration normal agricultural and food processing practices. The program does not account for atmospheric dispersion (i.e. input from atmospheric transport codes is needed) and for aquatic exposure pathways.

EXTERNAL EXPOSURE

From the specific activities of all deposited radionuclides a prognosis of the external gamma exposure of members of the public was made. To check its validity about 250 TLD-dosemeters were issued to members of the institute and their families. These detectors were either used as personal dosemeter or deposited at home at and below the window (area dosemeters; to account for shielding). Although the results (9) have to be interpreted on an individual base, the mean values agree remarkably well with the calculation assuming a 80 percent stay in houses and a mean shielding factor of 10.

It could be shown that at early times after aerosol deposition by heavy rainfalls initial run-off on paved areas leads to a gamma exposure reduction factor of about 0.7 as compared to grass land which in turn showed a shielding by a faktor of 0.7 due to surface roughness and initial migration of the radionuclides in soil. Later occuring weathering off effects on these paved places, streets, etc. are efficient in removing e.g. Cesium much faster than the slow migration into deeper soil layers in grass land. Thus we found dose rates above grass land to be by a factor of 4-5 higher than over paved areas one year after the same initial deposition. Such differences must be accounted for in assessments of external exposures.

INTERNAL EXPOSURE

The prognostic assessments made by ECOSYS for the nuclide specific concentrations as a function of time in various food products agreed very well with the measurements if the local deposition values were known (2). However, whole body counter measurements (4) indicated internal burdens of Cesium which were only one third of those predicted under the assumption of unchanged food consumption habits and of no influx of food from areas with less initial contamination. The actual extent of this factor and of changes in consumption habits are difficult to predict in a generic way.

CONCLUSIONS

In general the comparison of ECOSYS with experimental data showed very satisfying agreement. Therefore it can now be used as the basis of an early warning system in cases of elevated environmental radioactivity to optimize

countermeasures and to assess potential radiation exposures with high resolution in space and time. It needs nuclide specific contamination data for air and rain as input data. Complicated and very time consuming surveillance measuremets in agricultural products can then be restricted to the most relevant foodstuffs and locations. If relative radionuclide contaminations are known for some stations, simple gamma dose rate measurements and information on local precipitation at different stations can be used by ECOSYS to make reasonable estimates of local future radiation exposures on all relevant exposure pathways.

REFERENCES

1. Hötzl H., Rosner G., and Winkler R.:
   Ground deposition and air concentration of Chernobyl fallout radionuclides at Munich-Neuherberg, Radiochim. Acta 41, 181-190 (1987).

2. Müller H., Pröhl G., Voigt G., Lindner J.P.:
   Cäsium- und Jodgehalt wichtiger Lebensmittel nach dem Tschernobyl Unfall, Proc. 7th Workshop on Surveillance of Environmental Radioactivity, Neuherberg, Nov. 87, in press.

3. Jacob, P., Meckbach R., Müller H.M.:
   Reduction of external exposures from deposited Chernobyl activity by run-off, weathering, street-cleaning and migration in soil, Radiat. Prot. Dos. 1988, in press.

4. Berg D.:
   Ganzkörpermessungen im Raum München nach dem Reaktorunfall in Tschernobyl, loc. cit. Ref. 2.

5. Jacobi W., Paretzke H.G., Müller H.:
   Applicability of dynamic models to establishing derived intervention levels for foodstuffs, Proc. Seminar "Foodstuffs intervention levels following a nuclear accident", Luxembourg, April 87, in press.

6. Müller H. and Pröhl G.:
   Cesium transport in food chains - comparison of model predictions and observations. Proc. Workshop "Methods for Assessing the Reliability of Environmental Transfer Models Predictions", Athens, Oct. 87, in press.

7. Jacob P. and Meckbach R.:
   Shielding factors and external dose evaluation, Radiat. Prot. Dos. 1988, in press.

8. Paretzke H.G., Jacobi W., Jacob P., Müller H., Pröhl G., Henrichs K.:
   Radiological impact of the Chernobyl reactor accident on Germany, accepted by Nature, 1988.

9. Paretzke H.G., and Jacob P.:
   Erfahrungen nach dem Reaktorunfall von Tschernobyl und Folgerungen für die Überwachung der Umweltradioaktivität aus der Sicht der Strahlenforschung, loc. cit. Ref. 2.