ON-LINE VALIDATION OF A PREDICTION MODEL IN CASE OF NUCLEAR FALLOUT

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INTRODUCTION

After a large-scale nuclear fallout the early prediction of the exposure of the population to be expected is of great importance to enable early decisions on countermeasures to be taken and to optimize such decisions to ensure an maximum reduction of the expected exposure if required. This includes the prediction of the contribution of each exposure pathway, in particular the ingestion path, and the contribution of important foodstuffs to this path.

The prediction should be fairly precise which requires a number of data at an early stage after the accident on a nation-wide scale. This is impeded by a number of limitations in availability of data in the early phase which are caused by various reasons: Some important data such as the activity concentration integral in air, total wet and dry deposition and radionuclide concentrations in important fodder are not available before the end of the passage of the plume and the resulting fallout. But also the time delay in taking samples of relevant items on a nation-wide scale, delivery of the samples to the measuring laboratories and the need of sample preparation especially with regard to certain non-gamma-emitting radionuclides contribute to this unavailability of data relevant for the prediction in the early phase.

Despite these problems responsible authorities require a realistic assessment of the situation and a prediction of the exposure to be expected at an early phase of radionuclide release and fallout.

Therefore, in Austria the decision was taken to perform the required predictions of the ingestion exposure at various stages during and after the fallout ensuring that a very rough prediction of the exposure pathways is available at a very early stage and improvements of the prediction quality are obtained at various stages after fallout along with the arrival of more reliable and more accurate data in the course of the event. In addition, predicted values of activity concentration in fodder and in foodstuff are compared to actually measured values as they become available and the calculated values are improved accordingly.

PREDICTION PHASES

The prediction of the exposure was segmented into 4 major chronological stages at which certain data or data sets are expected to be available. These stages and the relevant input data which are presumed to be available or most reliable among those available and which are used for the calculations, are given in table 1.

Phase Nr.	Time after start of plume [d]	Criteria for initiating the prediction calculation	Scope and Accuracy of prediction	Relevant input parameters
1	2 - 4	after passage of a significant part of the plume	very rough	- activity concentration in air - gamma dose rate monitoring stations - precipitation data
2	4 - 6	after the passage of the major part of the plume	refined prediction	- activity concentration integral in air - activity concentration in precipitation - precipitation data
3	6 - 12	after the passage of the total plume	regionally refined prediction	- activity concentration integral in air - act. conc. in precipitation and soil samples (wet and total deposition) - precipitation data
4	10 - 16	after availability of fodder and foodstuff activity measurements	very refined, taking activity concentrat. in foodstuff into account	input data as in phase 3, further refinement by comparison to actually measured values in foodstuff

Table 1 Stages of exposure prediction after nuclear fallout

Computational predictions are performed with the prediction model ECOSYS (1) which had been adapted to Austrian climatic conditions and food consumption patterns several years ago and thereafter named OECOSYS (2). In order to enable proper predictions, the code requires a set of data independent of date of occurrence and the activity in the plume. These are preset as described before (3,4). Other input parameters are only established at or after the fallout. These comprise:

- activity concentration integral in air [Bq h m^{-3}]
- wet deposition of each radionuclide [Bq m^{-2}]
- amount of precipitation [mm]

The regional distribution of these values is required if for a specific region the exposure of persons living only on local foodstuff is to be derived, but also if the exposure of the general population in that area is to be predicted taking into account the transport of foodstuff from different regions of different fallout and growth stage levels within one country or in Europe.

In the early stage of a nuclear fallout only a few parameters will be readily available for evaluation in Austria:

1. data of the early warning system (336 gamma dose rate monitoring stations distributed all over Austria and transmitted in real-time and on-line to a central coordination and warning centre
2. activity concentration in air by a 6 on-line aerosol monitoring stations (total β-activity) and aerosol samples evaluated by gamma spectroscopy at a few places, mainly large cities and the Research Centre Seibersdorf
3. precipitation values by appr. 100 on-line meteorological monitoring stations which are also well distributed over Austria (TAWES - Teilautomatisches Wetter-Erfassungs-System)

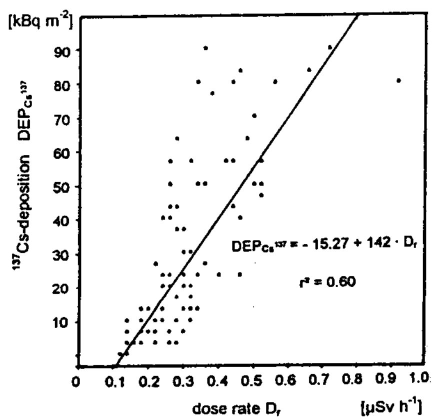
DERIVATION OF DEPOSITION VALUES FROM GAMMA DOSE RATE MONITORING

It has been demonstrated that from the on-line dose rate D_r monitoring early warning system the ^{137}Cs-activity deposition on ground $DEP_{Cs^{137}}$ (dry and wet) may be derived if data on radionuclide spectra are available (2,5):

$$DEP_{Cs^{137}}(t) = -15.27 + R_{Cs^{137}} \cdot D_r = -15.27 + 142 \cdot \frac{\sum k_i(x) \cdot g_i \cdot e^{-\lambda t}}{\sum k_i(\text{Chernobyl}) \cdot g_i \cdot e^{-\lambda t}} \cdot D_r \qquad (1)$$

k_i is the ratio of each radionuclide to ^{137}Cs, and g_i is the conversion factor D_r / DEP for each radionuclide. This takes into account that a relationship between dose rate monitored by the early warning system and ^{137}Cs-deposition values already was derived after the Chernobyl accident as displayed in Figure 1. Since the ratio of dose rate versus ^{137}Cs-deposition depends on the radionuclide distribution at the time of evaluation, the conversion factor may be arithmetically derived from the sum of the contribution of each radionuclide to the dose rate.

The deposition calculated by formula 1 is rather crude, but gives a quick and fairly reliable geographical distribution due to the large number of monitoring stations involved. The major reason for the rather crude estimate at this early stage is the fact that neither the complete activity concentration integral in air nor the total radionuclide deposition will be kown. Also the relationship between ^{137}Cs-activity deposition and gamma dose rate depends on the homogenuity of radionuclide distribution and on local variations of the ratio of the gamma dose rate displayed by the early warning station and ground deposition (2).



radio-nuclide	conversion factor g_i D_r / DEP	nuclide ratio	dose rate contribution
		on 10 May 1986	
^{99}Mo	$0.8.10^{-4}$	0.07	0.004
^{103}Ru	$3.0.10^{-4}$	1.29	0.38
^{106}Ru	$1.4.10^{-4}$	0.32	0.04
^{132}Te	$1.7.10^{-4}$	1.19	0.16
^{131}I	$2.6.10^{-4}$	4.22	1.07
^{132}I	$13.0.10^{-4}$	1.19	1.25
^{133}I	$3.6.10^{-4}$	0	-
^{134}Cs	$9.4.10^{-4}$	0.56	0.53
^{137}Cs	$3.8.10^{-4}$	1.00	0.38
^{140}Ba/La	$16.4.10^{-4}$	0.28	0.43
$\sum k_i(\text{Chernobyl}) \cdot g_i \cdot e^{-\lambda t}$			4.00

Figure 1 Relationship between gamma dose rate monitored by the early warning system and ^{137}Cs-activity deposition on 10 May 86 and contribution of radionuclides to dose rate

With a plume possibly passing for 2 - 8 days, the inhalation of air-borne activity and also the fallout will not be finished at the first prediction date. Therefore, as soon as the major part of the plume passed (4 - 6 days), a fact given when the amount of activity concentration in air is less than 5 % of original values and no further increases due to changing wind direction are forecasted, the second prediction calculation is performed. The input parameters include activity concentration in precipitation (wet deposition) replacing the less accurate deposition values derived from the early warning system by formula 1.

After 6 - 12 days the plume definitely has passed and besides precipitation activity also activity concentration of soil samples which had been collected and evaluated gamma-spectroscopically, will be available. This gives more reliable data on total wet deposition than precipitation activity data (times precipitation values) and therefore will replace these values in the input data set for the ECOSYS-prediction calculation.

ON-LINE VALIDATION PROCEDURE

After the end of fallout and with sufficient data for the primary input to the prediction code, a further improvement of the prediction is achieved by measuring samples of fodder and foodstuff and comparing the activity of these with values predicted by the model. A set of samples as given in table 2 is taken over the whole territory of Austria. The major fodder samples taken would be grass, maize and barley. The relative amount varies according to season. The dominant foodstuff considered in this evaluation of prediction accuracy will be milk since milk samples taken in the dairies from one milk collecting tour will average over an area of app. 0,05 - 0,25 km^2 (6), thus providing very reliable data for prediction comparison. Also other foodstuff samples would be taken in order to assure that activity concentrations of these are adequately predicted, but these are of less importance than milk and therefore a lower number of samples is being foreseen. The sample collecting plan fixes the type of sample taken, the approximate number of samples, the authority responsible for taking the sample, the measuring laboratory and the transport means of the sample to the laboratory in advance.

type of sample	appr. sample number	sample specification	sample taking spot
maize - fodder	80	1 kg of leave and 1 kg of cob *	near TAWES station
barley - fodder	80	1 kg corn at harvest or 1 kg plant 14 d before	near TAWES station
beets - fodder	80	1 kg beet (well cleaned of soil) *	near TAWES station
milk	~ 600	1 l (frequency depending on season)	each milk collecting tour
cereals	100 - 150	minimum 0,8 kg corn, 0,4 kg straw *	1 sample per 400 km^2
potatoes	50 - 80	1 kg at harvest or 1 kg plant 14-30 d before	1 sample per 800 km^2
leavy vegetables	80	1 kg, only outdoor plants,according to season	1 sample per 800 km^2
fruit vegetables	80	1 kg, several types of plants at season	1 sample per 800 km^2
fruit	80	1 kg, several types of fruit, at season	1 sample per 800 km^2
meat	~ 6000	min. 0,7 kg	statistical selection **

Table 2 Samples taken nationwide to test and improve on accuracy of prediction model
* mixed sample of 10 individual samples out of several fields
** beef: each 50th animal, veal: each 30th animal, pork: each 300th animal

CONCLUSION

The prediction model established in Austria to guarantee a rapid and reliable prediction of the activity concentration in foodstuff and the resulting ingestion dose after a nuclear fallout has been considerably improved by performing the required predictions at various stages after the arrival of the plume. The first very rough prediction uses the readily available data of on-line transferred data from the gamma dose rate stations of the early warning system and the meteorological monitoring system. In further prediction computer runs more refined input parameters such as precipitation and soil activity concentrations are used to obtain more precise results. In the later stage fodder and foodstuff activity concentrations as actually measured are used to further refine the model predictions.

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