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COSYMA: Ingestion Pathways and Foodbans

C. Steinhauer
Institut für Neutronenphysik und Reaktortechnik
Projekt Nukleare Sicherheitsforschung

Kernforschungszentrum Karlsruhe

KERNFORSCHUNGSZENTRUM KARLSRUHE
Institut für Neutronenphysik und Reaktortechnik
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Ingestion pathways and foodbans

C. Steinhauer

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COSYMA: Der Ingestionspfad und Nahrungsmittelverzehrverbote

Kurzfassung

Gegenstand des vorliegenden Berichts sind die Modelle zur Abschätzung von Nahrungsmittelverzehrverboten und von Ingestionsdosen und -risiken im Programmpaket COSYMA (Code System from MARIA), das vom Kernforschungszentrum Karlsruhe (KfK, FRG) und dem National Radiological Protection Board (NRPB, UK) im Rahmen des CEC - Forschungsprojekts MARIA (Methods for Assessing the Radiological Impact of Accidents) entwickelt wurde.

Die Auferlegung oder Aufhebung von Nahrungsmittelverzehrverboten kann sowohl basierend auf Radionuklidkonzentrationen in Nahrungsmitteln als auch auf Dosiskriterien angenommen werden. Individualdosen und Individualrisiken durch Ingestion werden stets unter der Annahme von lokaler Produktion und Verzehr der Nahrungsmittel abgeschätzt. Die Kollektivdosen und die Anzahl der von Gesundheitsschäden durch Ingestion betroffenen Personen in der Bevölkerung können entweder unter der Annahme von lokaler Produktion und Verzehr der Nahrungsmittel abgeschätzt werden, oder unter der Annahme, daß die in den betroffenen Gebieten angebauten Nahrungsmittel verzehrt werden, aber nicht notwendigerweise am Ort der Erzeugung.

Das Rechenprogramm ist sehr flexibel in der Behandlung von externen Ingestionsdatenbibliotheken verschiedener Herkunft. Der Benutzer hat weitreichende Möglichkeiten, den Rechenablauf zu beeinflussen, sowohl durch die Verwendung unterschiedlicher externer Dateien als auch durch die Modifikation von Parametern mit NAMELIST - Variablen.

Abstract

The subjects of this report are the models for the assessment of food restrictions and ingestion doses and risks in the program package COSYMA (Code System from MARIA), which was developed by the Kernforschungszentrum Karlsruhe (KfK, FRG) and the National Radiological Protection Board (NRPB, UK) in the frame of the CEC research project MARIA (Methods for Assessing the Radiological Impact of Accidents).

Food restrictions can be assumed to be imposed or withdrawn on the basis of either radionuclide levels in food or on dose criteria. Individual ingestion doses and risks are always assessed assuming local production and consumption of the foodstuffs. The collective doses and the number of health effects in the population from ingestion can be estimated either with the assumption of local production and consumption of the foodstuffs, or with the assumption that all produce in the contaminated areas is consumed somewhere, but not necessarily locally.

The code is very flexible in the handling of external ingestion data libraries of different origin. The user has ample possibility to influence the calculations by using different external data files as well as by modifying parameters with NAMELIST variables.

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Part I

Overview

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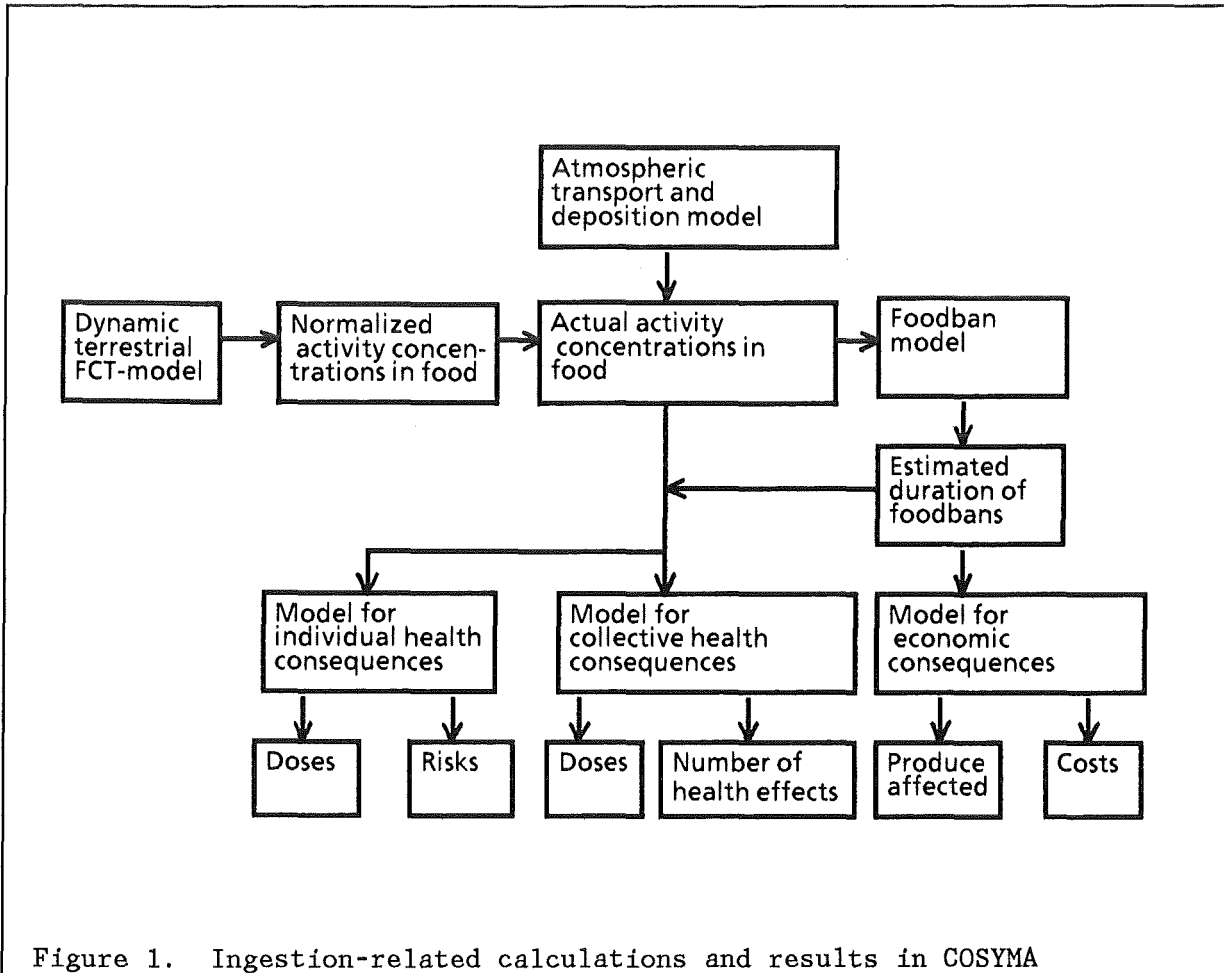
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1. THE INGESTION MODEL OF COSYMA

1.1 GENERAL FEATURES

The consequences resulting from the ingestion of terrestrial foodstuffs contaminated after accidental releases of radionuclides into the atmosphere are assessed in the subsystems NL and FL of COSYMA [1]. Figure 1 shows the end-points of the calculations and the models involved:



All calculations require data about specific time-dependent activity concentrations in food, which are in COSYMA assumed to refer to the foodstuffs ready for consumption. These data are calculated with a dynamic foodchain transport (FCT) model. Since such models themselves are normally rather complex and require significant computing times, they cannot be included in the COSYMA code to calculate the corresponding data during an accident consequence assessment (ACA) run. Instead, they are used to precalculate and tabulate the required information with a suitable normalization in external data libraries.

During an ACA run, the actual specific activity levels in food can be obtained by combining the normalized activity concentrations from the foodchain transport model with the activity concentrations in air or on the ground in each grid point predicted with one of COSYMA's atmospheric transport and deposition models. In COSYMA, the coupling between both model types is done with the total

activity initially deposited on the ground. At present, no distinction is made between activity levels in food caused by dry and wet deposition processes.

The actual activity concentrations in food together with data for food intake, internal dosimetry, radiation induced health risks, population density and annual agricultural production is used to assess the health and economic consequences in the different modules of COSYMA.

The evaluation of individual doses and risks from the ingestion pathways is always carried out under the assumption that all food consumed is produced at the point of consumption, and that the required amount of food is produced in each grid element (local production and consumption approach).

For the evaluation of collective ingestion doses and risks, COSYMA offers two models. The first is the local production and consumption model mentioned above, which requires information about the number of individuals in the grid elements. The second model is based on the assumption that all contaminated food produce is consumed somewhere (agricultural production approach) and requires information about the amount of agricultural production in the grid elements which is used for human consumption.

All endpoints can be generated with or without taking the effects of food restrictions into account. In the former case, food bans can be assumed to be imposed or withdrawn on the basis of intervention levels either based on activity levels in food or on individual doses, and the ban duration is estimated in the foodban module of COSYMA.

1.2 TREATMENT OF SEASONAL EFFECTS

Previous investigations have shown, that the time of year when an accident occurs has a marked influence on the subsequent transfer of radionuclides through the terrestrial foodchains [2] and thus on the ingestion-related accident consequences [3]. The extreme examples are a release in winter when relatively few or no crops are grown and many livestock are housed indoors, and a release in summer at the height of the growing season when cattle and sheep are grazing outdoors.

In COSYMA, seasonal effects are taken into account by using different activity-in-food data libraries for accidents occurring at different times of the year. In theory, a large number of such files could be used, but considerations on the amount of data which can be handled restrict the number, and COSYMA approximates seasonal effects by using two data sets, one for a release in the season with the minimum impact on the contamination of the agricultural products, and one for the season when the highest impact occurs. For European conditions, the two extremes can for instance be represented by a release on January 1st as a representative for the winter season "November to March", and by a release on July 1st as a representative for the summer season "April to October".

During an ACA run, the release date, which is inferred from the starting time for the atmospheric sequence, is attributed either to the winter or to the summer period, and the appropriate data set is selected by the program. In addition, it is also possible to generate results for one of the above time periods alone or to use a single data set for all times of the year.

2. INGESTION DATA

2.1 EXTERNAL FILES AND NAMELIST INPUT

Two categories of ingestion data can be distinguished: those which are kept in external data files, and those which are specified with NAMELIST input. The external files are made known to the code at runtime with the Job Control Language, and the user has the possibility to change these data by attaching other external files. For the NAMELIST input, default values are preset in the code; at runtime, these can be modified selectively by the user.

The first category comprises the data which require significant storage space, e.g. the agricultural production grids, and the data from all models which cannot be made part of the COSYMA code itself, e.g. the dynamic terrestrial foodchain transport models. With respect to the latter, COSYMA can be used with results of any model which is capable of calculating normalized activity concentrations in food in an appropriate format at a series of times after the deposit. There is no restriction to a specific sequence of foodstuffs or times in the code, which allows a considerable flexibility in the handling of data files of different origin.

The NAMELIST input consists of runtime options, which select the models to be considered, and of variables, which act as parameters in the calculations of foodbans and of the ingestion doses and risks. The modification of the parameter values offers a powerful means to influence the performance of the algorithms without having to change the source code. - The default values for all ingestion NAMELIST variables are described in chapter "Input group INGESTI" in Part III and PART IV of the COSYMA USER GUIDE [4].

2.2 DATA FILES PROVIDED WITH THE PROGRAM PACKAGE

For the external ingestion data libraries, a set of default files is routinely included in the COSYMA program package, which can be used for all standard applications.

The default files for the activity-in-food data are for general use within the EC in the absence of site specific information. At present, they contain data for ten foodstuffs and a large number of LWR-typical nuclides and actinides (see Table 1 on page 4).

In addition, several data libraries for special applications are also available, for example files containing data for activation products from fusion reactors, and files which were developed specifically for the application of COSYMA in South Korea.

These special files can be provided on request. An actual list of all available ingestion data libraries can be found in the chapter "Input group INGESTI" in Part III and PART IV of the USER GUIDE, which also contains details about the origin of the data and the foodstuffs and radionuclides contained in the various files.

Foodstuffs

MILK - fresh milk from dairy cows
COWSMEAT - cows meat (including veal) / COWLIVER - cows liver
SHPMEAT - sheep meat / SHPLIVER - sheep liver
PORK - pork
GREENVEG - green vegetables (leafy + non-leafy)
ROOTVEG - root vegetables / POTATOES - potatoes
GRAINPRD - grain products

Radionuclides

SR- 89	SR- 90	Y - 90	Y - 91	ZR- 95	NB- 95	MO- 99
RU-103	RU-106	TE-127M	TE-129M	TE-132	I -129	I -131
I -133	I -135	CS-134	CS-136	CS-137	BA-140	CE-144
PU-238	PU-239	PU-240	PU-241	PU-242	AM-241	AM-242M
AM-243	CM-244					

Table 1. Foodstuffs and radionuclides in the activity-in-food EC-data files IG-91/AX

3. COSYMA AND THE INGESTION PROGRAM SYSTEM COSING

In addition to the ingestion part of COSYMA, there is a stand-alone ingestion program system COSING, which is the successor of the program UFOING described in [5]. COSING contains an accident consequence assessment part and several auxiliary and preprocessor programs.

The ACA part allows some more detailed investigations than possible with the ingestion model of COSYMA. For example, it provides very detailed information about the contributions of radionuclides, foodstuffs, and radionuclides per foodstuff to the results, and estimates age-dependent organ doses from ingestion under the assumption of local production and consumption of the foodstuffs using the activity-dose coefficients concept developed for UFOING.

The preprocessor part consists, among others, of all stand-alone programs which are required to generate the external data files used by COSYMA. They perform such tasks as the restructuring, reducing, expanding, or modifying the original files delivered from the external models to make them fit into the COSYMA data file requirements. They also generate the data files of activity-risk coefficients used for assessments of the time-dependent cancer risks in the population, and other COSYMA-specific files.

4. GUIDE TO THE DOCUMENT

This report refers to the version of COSYMA designated 91/1. It is one of a series of documents about the COSYMA program system, and some general knowledge of the basic features of COSYMA is assumed.

The document consists of four parts, which are summarized below.

4.1 PART I

This part gives a brief description of the models, the data, and the results of the ingestion part of COSYMA. Readers only interested in obtaining an overview of the general features may stop here.

4.2 PART II

Part II explains the ingestion models and algorithms, and the ingestion NAMELIST variables. A knowledge of this part is helpful for the interpretation of the accident consequence assessment results concerning the ingestion pathways, and essential for a successful modification of the default values provided for the ingestion NAMELIST variables.

The possibility of COSYMA to work with external files of activity-in-food data of different origin requires a somewhat complicated treatment of the foodstuffs in the code and also some knowledge of the data when specifying certain NAMELIST variables. This matter is addressed in the first two chapters. The other chapters describe the calculation of the foodbans and of the individual and collective doses and risks from ingestion.

With a few exceptions, in the discussion of the NAMELIST variables emphasis is laid on their function as parameters which influence the performance of the calculations rather than on how to specify their values; the latter is dealt with in detail in the USER GUIDE.

4.3 PART III

Part III describes the default food consumption rates and the external data files for the normalized specific activities in food, the ingestion dose- and risk conversion factors, and the agricultural production data, which are routinely included in the COSYMA program package.

4.4 PART IV

Part IV is concerned with the ingestion data files in general. It explains technical details of the files which must be known when producing them, as for example the exact file structure, the file naming conventions, and peculiarities of the data which are to be observed. A list of variable names frequently used in this document and in the ingestion parts of the COSYMA source code is also given.

This information is especially of interest for users who wish to modify or replace any of the data files COSYMA uses for accident consequence assessment

calculations with the inclusion of the ingestion pathways. If only the DEFAULTS file containing the default values for the ingestion part of COSYMA is to be expanded, it is sufficient to read the corresponding chapter and ignore the rest. In all other cases, the entire text of this part should be read.

The generation of some of the ingestion files requires data from files not routinely supplied with the COSYMA program package, and the description of these additional files is included. Not included is the description of the files of the gridded data for the agricultural production used for human consumption and for the agri-economic production, which is given in Chapter VI of the USER GUIDE.

5. REFERENCES

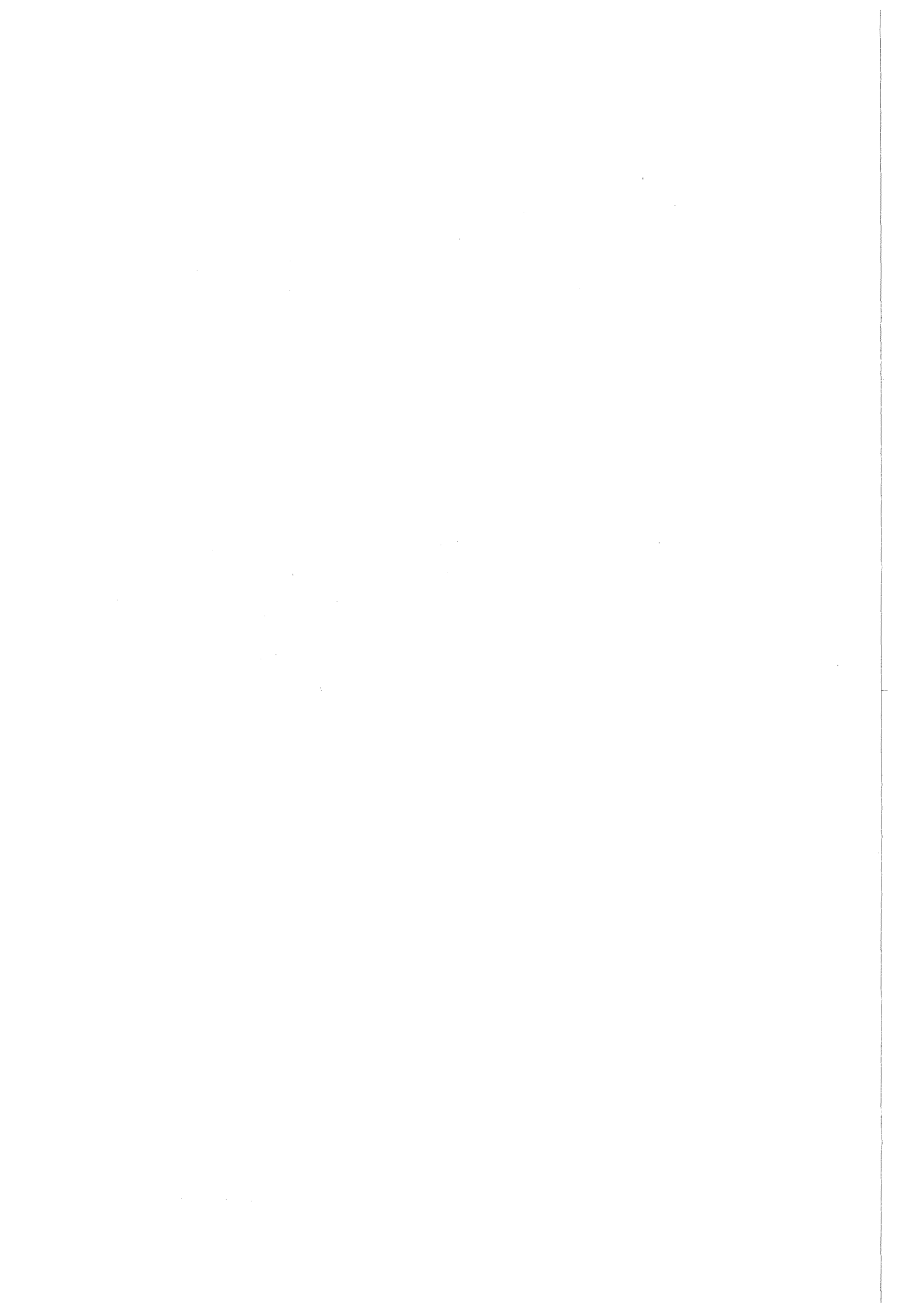
- [1] COSYMA: A New Program Package for Accident Consequence Assessments. Joint report by Kernforschungszentrum Karlsruhe GmbH and National Radiological Protection Board. Brussels, Report EUR 13028 (1991).
- [2] J. R. SIMMONDS. The Influence of Season of the Year on the Transfer of Radionuclides to Terrestrial Foods following an Accidental Release to Atmosphere. Chilton, NRPB-M121 (1985).
- [3] J. R. SIMMONDS. The Influence of Season of the Year on the Predicted Agricultural Consequences of Accidental Releases of Radionuclides to Atmosphere. Chilton, NRPB-R178 (1985).
- [4] COSYMA: User guide. Compiled by I. Hasemann and J.A. Jones. Brussels and Karlsruhe, Report EUR 13045/KfK-4331B (1991).
- [5] C. STEINHAEUER. UFOING: A program for assessing the off-site consequences from ingestion of accidentally released radionuclides. Karlsruhe, KfK-4475 (1988).

Part II

Models, algorithms and NAMELIST variables

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1. FOODSTUFFS IN COSYMA

For an ingestion-related accident consequence assessment with COSYMA, various ingestion data are needed, as for instance normalized activity levels in food or the amount of agricultural produce which is used for human consumption or for the evaluation of the economic impact of foodbanks. One main aim in the software design of the COSYMA ingestion model was the ability to operate with foodchain data of different origin, which may differ from each other not only by the numerical value for a given foodstuff, but, for example, also by the foodstuffs themselves.

The above design requirement made it necessary to treat the foodstuffs not as items once defined and then hardwired in the code, but as manipulatable objects which can be adjusted outside the code to suit the constraints given by the data under consideration. For this purpose, four different categories of foodstuffs, henceforward referred to as **foodstuff levels**, are distinguished:

- **LEVEL 1** is made up from the foodstuffs for which normalized specific activity concentrations in food are available from a terrestrial foodchain transport model.
- **LEVEL 2** specifies the parameterization of the dose- and risk results with respect to the foodstuffs; it is the only one which is not defined by the availability of data.
- **LEVEL 3** consists of the foodstuffs for which agricultural production for human consumption data are available.
- **LEVEL 4** consists of the foodstuffs for which agri-economic data are available.

The foodstuffs on Levels 1, 3 and 4 are fixed in the sense that they are defined by the files containing the corresponding data, and the user has no way to influence them except by using other data files.

The foodstuffs on Level 1 form the basis for all ingestion calculations. The logical connection of the foodstuffs on the other levels with the Level 1 foodstuffs is made by a series of **pointer arrays**, which are included in the NAMELIST group INGESTI:

- Level 2 is connected with Level 1 by means of an array named **L1L2**; Level 3 is connected with Level 1 by two arrays called **L1L3FR** and **L1L3PR**; and, finally, an array with the name **L1L4** connects Level 4 with Level 1.

In the following sections, the foodstuff levels and the level pointers are explained in detail, and examples for the specification of the pointer arrays are given.

The big advantage of the pointer technique is the flexibility in the adaptation to changes in the data bases without having to change the source code. The obvious disadvantage is, that this concept is in general an unfamiliar one for the user and that the task of setting up the cross reference tables for the pointer arrays is not easy. However, default tables are provided for all standard applications of COSYMA, and in the normal case no user action is required.

1.1 SPECIFICATION OF THE FOODSTUFF LEVEL POINTERS

Figure 1 gives an example for a configuration of foodstuffs in COSYMA, and Table 1 shows the corresponding specification of the NAMELIST variables.

Foodstuffs on Level 1 (from data files)					
Number 1 - 5:	MILK	COWSMEAT	COWLIVER	PORK	SHPMPEAT
Number 6 - 10:	SHPLIVER	GREENVEG	ROOTVEG	POTATOES	GRAINPRD
Foodstuffs on Level 2 \equiv Foodstuffs on Level 1					
Foodstuffs on Level 3 (from data files)					
Number 1 - 5:	FR. MILK	PR. MILK	COWSMEAT	COWLIVER	SHPMPEAT
Number 6 - 9:	SHPLIVER	GREENVEG	ROOTCRPS	GRAINPRD	
Foodstuffs on Level 4 (from data files)					
Number 1 - 3:	MILK	LIFESTCK	CROPS		
Values of pointer L1L2 (NAMELIST input)					
Number 1 - 5:	1,	2,	3,	4,	5,
Number 6 - 10:	6,	7,	8,	9,	10,
Values of pointer L1L3FR (NAMELIST input)					
Number 1 - 5:	1,	3,	4,	0,	5,
Number 6 - 10:	6,	7,	-8,	8,	9,
Values of pointer L1L3PR (NAMELIST input)					
Number 1 - 5:	2,	0,	0,	0,	0,
Number 6 - 10:	0,	0,	0,	0,	0,
Values of pointer L1L4 (NAMELIST input)					
Number 1 - 5:	1,	2,	2,	0,	2,
Number 6 - 10:	2,	3,	3,	3,	3,

Table 1. Example for the specifications of the foodstuff level pointers

For all pointers, the *index* of an array always refers to the foodstuff with the corresponding number on the base Level 1, and the *value* specifies, which foodstuff on another level is connected to it by means of the position number of the foodstuff on the target level. For example, L1L3FR(2)=3 means, that foodstuff number 2 on Level 1 (COWSMEAT) is connected to foodstuff number 3 on Level 3 (COWSMEAT), and L1L4(7)=3, that foodstuff number 7 on Level 1 (GREENVEG) is connected to the item number 3 on Level 4 (CROPS).

A zero for the pointers L1L3FR, L1L3PR and L1L4 indicates, that for a given Level 1 foodstuff no corresponding item exists on the target level. A value of zero for L1L2 and a negative value for L1L3FR have a special meaning which is explained in the following sections.

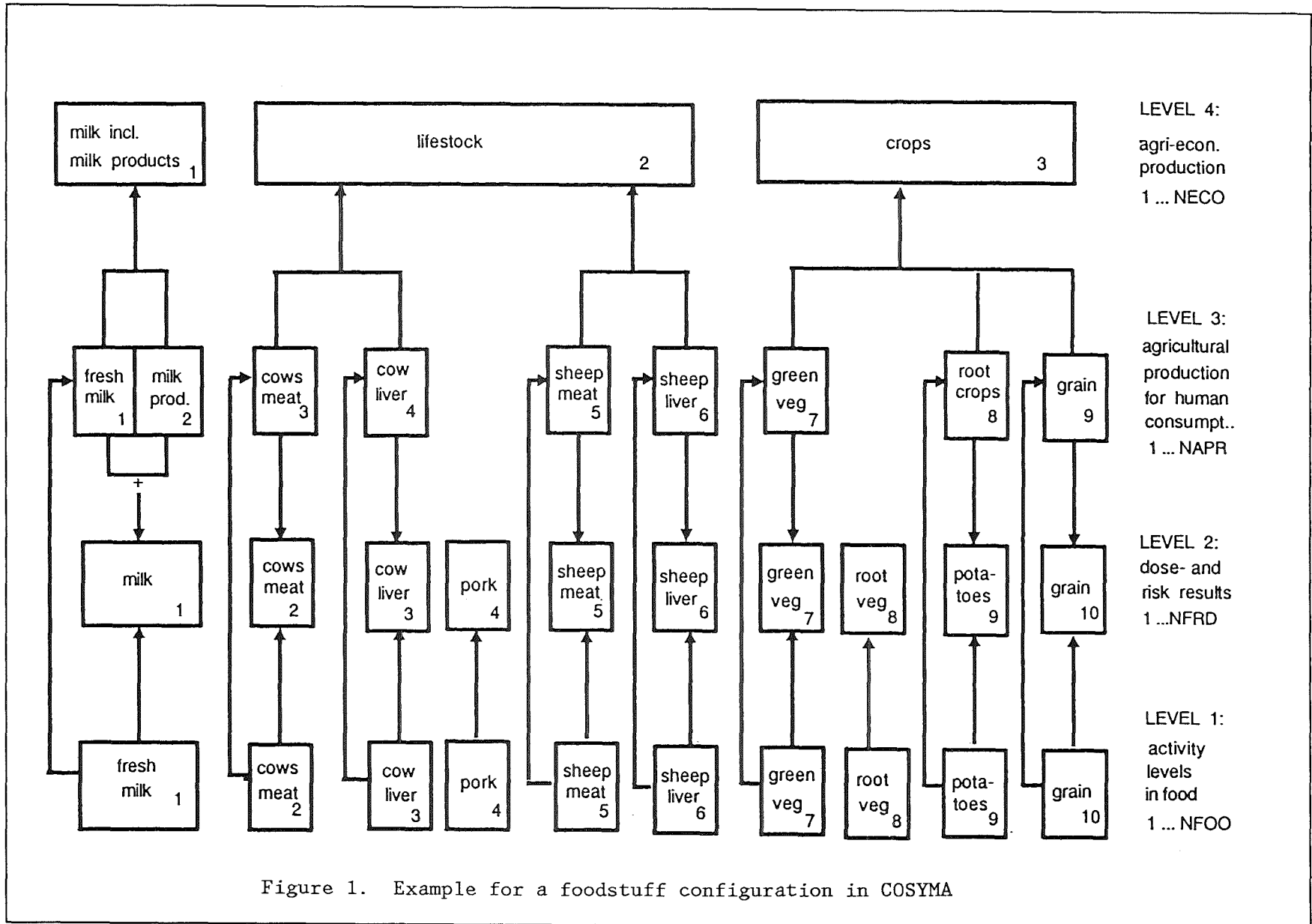


Figure 1. Example for a foodstuff configuration in COSYMA

1.1.1 Foodstuff Level 2 and pointer L1L2

Level 2 represents the degree of detail with respect to the foodstuffs in the assessments of individual and collective doses and risks in the sense, that the corresponding results R for several Level 1 foodstuffs f1 can be added together to results for some other category F2:

$$\bar{R}(F2) = \sum_{f1 \in F2} R(f1)$$

In contrast to the Levels 1, 3 and 4, the definition of the foodstuffs on Level 2 is not implied by some external data file, but is entirely up to the user. First, it must be decided which of the Level 1 foodstuffs shall be added together. Then, this decision must be made known to the code with the NAMELIST input: with a variable named IGNFRD it is specified how many food items are to be considered on Level 2, the pointer array L1L2 connects Level 2 with Level 1, and with a variable FRDNAM names are given to the Level 2 foodcategories.

To give an example, it is assumed that the user may not be content with the definition of Level 2 in Table 1 on page 1-2, which is "Level 2≡Level 1" by default. Instead, the results for meat and liver from cows and sheep, respectively, and also for all edible plant products are to be added together. This can be implemented with the following NAMELIST input:

Foodstuffs on Level 1 (from data files)						
Number 1 - 5:	MILK	COWSMEAT	COWLIVER	PORK	SHPMEAT	
Number 6 - 10:	SHPLIVER	GREENVEG	ROOTVEG	POTATOES	GRAINPRD	
Number of foodstuffs on Level 2 (NAMELIST variable IGNFRD)						
IGNFRD = 5						
Names of foodstuffs on Level 2 (NAMELIST variable FRDNAM)						
Number 1 - 5:	MILK	COWS M+L	SHP M+L	PORK	ALLCROPS	
Values of pointer L1L2 (NAMELIST input)						
Number 1 - 5:	1,	2,	2,	4,	3,	
Number 6 - 10:	3,	5,	5,	5,	5,	

The concept of a Level 2 was originally introduced to facilitate ACA-calculations with the stand-alone ingestion program system COSING. This code provides very detailed, very useful, but unfortunately also very lengthy output for the contributions of nuclides, foodstuffs, and nuclides per foodstuffs for the various results. Thus, Level 2 was an aid to reduce this information somewhat by enabling to consider only the degree of detail of interest with respect to the foodstuffs.

Since most of the results are summed up over the foodstuffs anyway, the ingestion part of COSYMA does not have the original problem. Here, a distinction between the two levels is not really necessary, which is reflected by the fact, that in all default setups of COSYMA, Level 2 is made identical to Level 1 (see Figure 1 and Table 1).

For all standard applications, the COSYMA user need not to be concerned about the Level 2. However, there is one important exception which may be of interest even for the casual COSYMA user: *by setting L1L2 of a Level 1 foodstuff to zero, it is disregarded in all calculations (including foodbans)¹ and on all levels.* This is the easiest possibility to do parameter studies with only one or a few foodstuffs involved. The example below shows how the NAMELIST input looks like if only MILK is to be taken into account:

```

Foodstuffs on Level 1 (from data files)
Number 1 - 5:      MILK  COWSMEAT  COWLIVER      PORK  SHPMEAT
Number 6 - 10:   SHPLIVER GREENVEG  ROOTVEG  POTATOES  GRAINPRD

Number of foodstuffs on Level 2 (NAMELIST variable IGNFRD)
IGNFRD = 1

Names of foodstuffs on Level 2 (NAMELIST variable FRDNAM)
Number 1      :      MILK

Values of pointer L1L2 (NAMELIST input)
Number 1 - 5:      1,      0,      0,      0,      0,
Number 6 - 10:     0,      0,      0,      0,      0,

```

1.1.2 Foodstuff Level 3 and the pointers L1L3FR and L1L3PR

In the calculations of the ingestion doses and risks with the agricultural production method, the normalized specific radionuclide concentrations in the foodstuffs are multiplied with the annual agricultural production for human consumption in the grid element (see chapter "Agricultural production approach"). As a consequence, the program must know, which Level 1 foodstuff and which Level 3 foodstuff belong together.

Ideally, there should be a one-to-one correspondence of the foodstuffs on these two Levels. However, this is in general not the case, since the foodstuffs on Level 1 are determined by the foodchain transport model which generated the activity-in-food data, and the degree of detail for the foodstuffs on Level 3 depends on the availability of the corresponding statistical information for a country or a region.

In addition, each individual Level 1 foodstuff may be assumed to be consumed in two forms distinguished by the initial delay times in COSYMA (see chapter "4. Doses and risks from ingestion"). On Level 3, this assumption is realized by the possibility to attach production data for the two forms to the corresponding Level 1 foodstuff, if such data are available: Pointer array L1L3FR connects the Level 3 item with the shorter delay time ("FR") to a Level 1 foodstuff, and array L1L3PR the Level 3 item with the longer delay time ("PR").

From Figure 1 it can be seen, that four different cases can be distinguished:

1. One-to-one correspondence between Level 1 and Level 3 (example: GRAINPRD).

¹ In all other cases, L1L2 has no influence on the calculation of foodbans.

2. For one Level 1 foodstuff, there exist two items on Level 3 (example: MILK on Level 1, FR.MILK and PR.MILK on Level 3).
3. For two Level 1 foodstuffs, there is only one foodstuff on Level 3 (example: POTATOES and ROOTVEG on Level 1, ROOTCRPS on Level 3).
4. No corresponding agricultural production item available for a Level 1 foodstuff (example: PORK).

Table 1 on page 1-2 shows, how the example configuration is implemented with the pointer arrays:

The Level 1 foodstuff MILK is represented by the first position in the arrays L1L3FR and L1L3PR. The values L1L3FR(1)=1 and L1L3PR(1)=2 show, that MILK is to be connected with the first item FR.MILK and the second item PR.MILK on Level 3. Because of the absence of any more secondary Level 3 items for the other Level 1 foodstuffs, all other values of L1L3PR are zero.

The fourth foodstuff on Level 1, PORK, has no corresponding match on Level 3 at all. In Figure 1 it is assumed, that this means that pork cannot be taken into account in the calculations, and L1L3FR(4) is zero. However, the user may be of the opinion, that, as an approximation, results for pork shall be calculated with the activity levels for PORK, but with the agricultural production data for COWSMEAT. This assumption could be realized with L1L3FR(4)=3.

For the foodstuffs number 8 and 9 on Level 1, ROOTVEG and POTATOES, a decision must be made, which of the two activity levels shall be used in connection with the production data for ROOTCRPS. In the example, this is assumed for POTATOES, and L1L3FR(9)=8. L1L3FR(8) is set to -8 as an indication, that it logically also belongs to ROOTCRPS, but cannot be taken into account. An exchange of the signs would select ROOTVEG instead of POTATOES.

The specification of L1L3FR for the other Level 1 foodstuffs is straightforward, since there is a one-to-one correspondence.

1.1.3 Foodstuff Level 4 and pointer L1L4

Level 4 consists of the foodstuffs, for which agri-economic production grid data are available; these foodstuffs are connected to the Level 1 foodstuffs with the pointer array L1L4. As far as experience with the COSYMA data bases is concerned, the parameterization of the data on this level is in general less detailed than on Level 1 because of the lack of corresponding statistical information. This is reflected in the example configuration in Figure 1 and Table 1. Here, L1L4(4) is zero, because PORK is not included in the Level 4 data for LIFESTCK.

2. GENERAL CONSIDERATIONS FOR SOME INGESTION NAMELIST VARIABLES

Most of the input variables in NAMELIST group INGESTI depend on the external data, e.g. on the activity levels in food. An example are the foodstuff level pointers, which depend on number and types of the Level 1 foodstuffs. This has two consequences:

1. The default values depend on the external data files attached at runtime.
2. Changing the default values requires some knowledge of the external data files.

The first consequence lead to the introduction of default setups bearing names which can be addressed with NAMELIST variable CIGSET. The second consequence implies, that the user always should consult the chapter "Input group INGESTI" in Part III and IV of the COSYMA USER GUIDE [1] before changing the preset default values; this is especially important for a specification of the NAMELIST variables FBDLAY, FDELAY and PDELAY. The quoted chapter contains for all external files a list of the corresponding default values and of the properties of the data relevant for the ingestion NAMELIST variables.

2.1 DEFAULT SETUP CODES, DATA TYPE CODES, NAMELIST VARIABLE CIGSET

Since the default values in input group INGESTI largely depend on the foodstuffs, they will in general be different for the various activity-in-food files supplied with the COSYMA program package. Also, for the same external file, there may be different default values, for instance one for LWRs and one for releases with significant fractions of actinides.

One complete set of default values for all NAMELIST variables in input group INGESTI is referred to as a **default setup**, and each default setup is characterized by a name called the **default setup code**. The first seven characters of this name characterize the activity-in-food data it belongs to, the last character is used to distinguish between different setups to the same data type.

All sets of default setups provided with the COSYMA program package are described in the USER GUIDE. Their values are collected in a file with the name DEFAULTS; this is the only ingestion data file which is *formatted*. The user is not expected to alter the existing values in this file. However, he may add setups of his own design with appropriate default setup codes to the file. How to do this is explained in Part IV.

A specific default setup is requested with the NAMELIST variable CIGSET of input group RESULTS. The default value in COSYMA for CIGSET selects the general setup for the activity levels in food data for use in the EC (unless it was re-defined for special applications).

During program execution, COSYMA will first inspect the DEFAULTS file for a default setup with the name given by CIGSET. If it finds one, the information contained in the DEFAULTS file is used to initialize the NAMELIST variables with the corresponding values, which can then be modified selectively by the user with NAMELIST group INGESTI. If none is found, a warning message is issued, but execution will continue. In this case, all values must be specified with the NAMELIST input (else program crash).

In addition, to avoid total confusion, it must be prevented that a mixup of default values and foodchain data occurs at runtime, for example by using default values for the EC together with activity-in-food data for Korea and activity-risk coefficients derived with the old ECOSYS data for Germany. Therefore, each external file referring to the same activity-in-food data is characterized by a name called the **foodchain data type code**, which is contained in the first record in the file. The first seven characters of this name characterize the data; character eight is always the letter 'X'. During program execution, COSYMA compares the name given by CIGSET with the foodchain data type code read from the data files used, and stops with an error message if the first seven characters are not equal.

2.2 INITIAL DELAYS AND PREPARATION LOSSES

2.2.1 Initial delays; NAMELIST variables FBDLAY, FDELAY and PDELAY

An **initial delay** is the time span between the production (i.e. slaughter, cropping) of a foodstuff and the time the consumption is assumed to begin. For nuclides with radioactive half lives \lesssim the delay time, the specific activity concentrations in food decrease significantly during this time due to the radioactive decay. Initial delays may or may not be already taken into account in the foodchain transport models which generated the activity-in-food data; the delay times implicitly contained in the files provided with the COSYMA program package are shown in the USER GUIDE.

In the COSYMA ingestion model, the user can specify initial delay times to be considered when calculating foodbans (variable FBLAY; see " 3. Foodbans") or doses and risks (variables FDELAY and PDELAY; see " 4. Doses and risks from ingestion"). In the algorithms, these delays are taken into account by an exponential factor $\exp[-(\ln 2/\text{radioactive half life}) \times \text{delay time}]$, which is multiplied with the activity level in food. Therefore, they represent *minimum delays between harvest and consumption additional to those implicitly contained in the foodchain transport model data*.

As an example, the specification of the negative delay time contained in the data can be used to undo the corresponding delay, so that the resulting activity level in food refers to the foodstuff ready for consumption immediately after harvest.

2.2.2 Preparation losses

Losses of activity due to food preparation processes such as washing and peeling etc. are already taken into account in the foodchain transport models which generated the data. No further means is provided to consider additional processes, so that the only influence the user has in this matter is the complete exchange of the corresponding data files.

For information, the reduction factors assumed in the models are included in the descriptions of the data files in the USER GUIDE (Chapter "Input group INGESTI").

3. FOODBANS

3.1 DECISION ABOUT FOODBANS

3.1.1 General features

Foodbans can be assumed to be imposed or withdrawn on the basis of intervention levels (ILs) either based on activity levels in food or on individual doses (see Figure 2 on page 3-2). In both cases, the intervention levels for the imposition and withdrawal of the bans need not be the same and the user has considerable freedom to specify his requirements. Output from the foodban model is a data set of "foodban flags", which give for each grid element the estimated ban duration for each foodstuff in coded form. This data set is used by all modules of COSYMA/COSING requiring information about foodbans.

If based on activity levels, the user can input the intervention levels for a range of nuclide groups and foodstuffs defined by himself. For each foodstuff, the program will sum up the concentrations of the nuclides from each nuclide group for comparison with the corresponding intervention level.

If based on doses, the user can select which organs and foodstuffs are to be taken into account for banning. Individual foodstuffs can be combined to form foodgroups in such a sense, that the sum of the doses from all foodstuffs in each group will be compared with an intervention level assigned to the whole group.

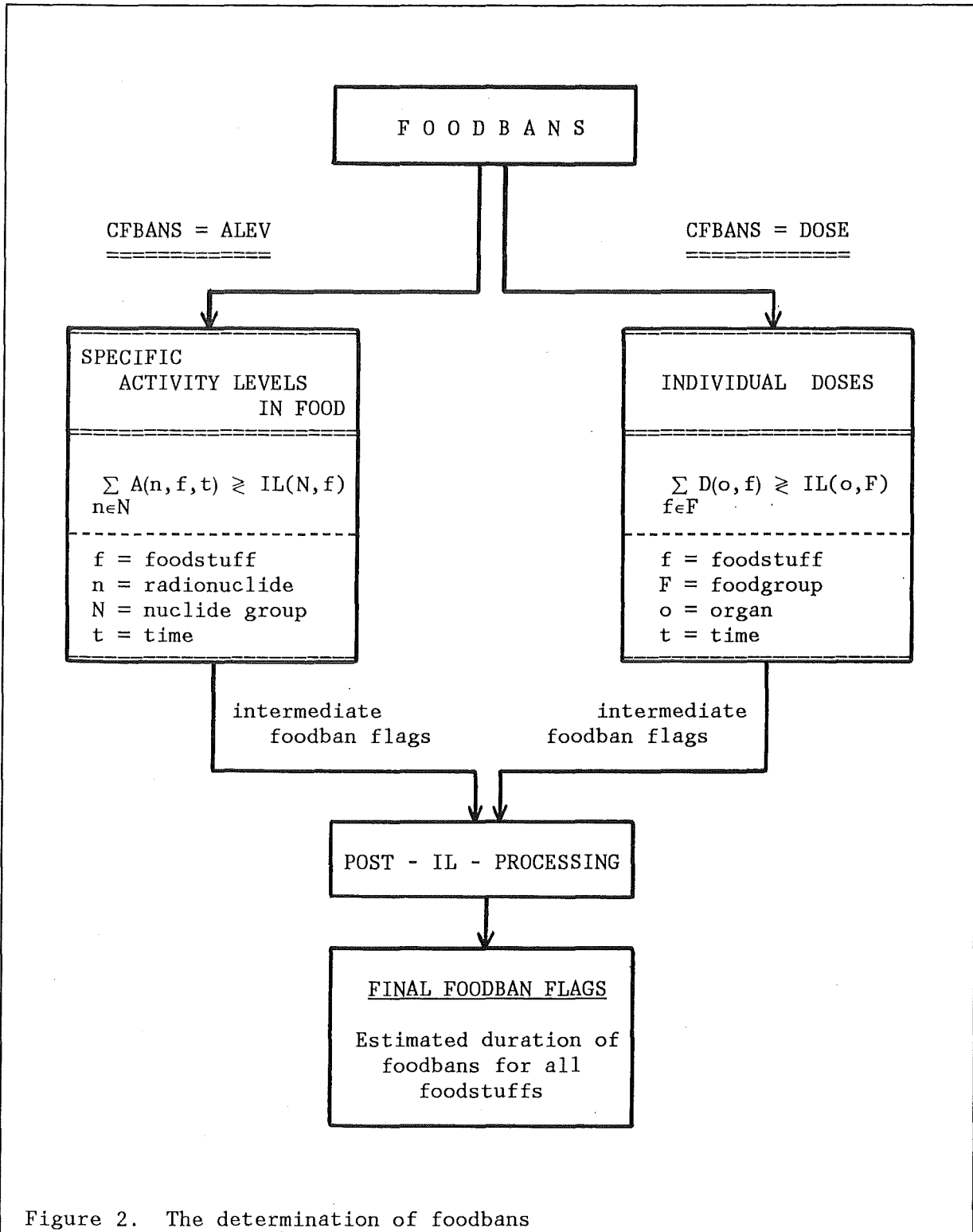
In the calculations of the foodban durations with either of the two methods, losses of activity during normal food processing are always implicitly accounted for, because these processes are already considered in the foodchain transport models and are thus contained in the normalized activity concentrations in food data. Initial delays between the production of a foodstuff and the time at which the consumption is assumed to begin may or may not be included in the normalized activity levels in food data; the user has the possibility to specify additional delays for each foodstuff when calculating foodbans.

Both the delay times and the foodgroups for banning, i.e. for the comparison with intervention levels, are valid for the purpose of banning alone and are not used outside the foodban module.

After the calculation of the foodban flags in the way described above, two modifications to the flags are made in the ban module ("post-IL-processing"). The first one is always carried out and takes account of the other long-term countermeasure 'relocation': in COSYMA it is assumed that in a relocated area no agricultural production will take place until resettlement. Therefore, in all grid elements affected by relocation, all foodstuffs for which either no foodbans or a foodban duration shorter than the duration of relocation was calculated, will receive a foodban flag corresponding to the relocation time span.

The second modification is optional and can be steered by the user: it is possible to assign common foodban flags to different foodstuffs in the sense that the most restrictive ban time found for these foodstuffs is assigned to each individual foodstuff.

For each of the methods mentioned above, default values for the nuclide- and foodgroups for banning, the organs, the intervention levels, and the delay times are provided in COSYMA; the current setup can be found in the COSYMA USER GUIDE.



3.1.2 Foodbans assumed to be based on activity levels in food

The model for evaluating foodbans under the assumption of intervention levels based on activity levels in food is selected with the option CFBANS = ALEV of input group RESULTS. Table 2 on page 3-4 summarizes the foodban algorithm and the NAMELIST variables which influence the calculations.

For each individual foodstuff, the total activity per unit amount (i.e. [kg] or [l]) resulting from all radionuclides belonging to a given nuclide group is calculated. The 'foodban on' condition is met for the foodstuff if the corresponding intervention level is exceeded for any of the nuclide groups, and the 'foodban off' condition if the intervention levels are not exceeded for all nuclide groups.

The specific activity levels in food are calculated under the assumption that the foodstuffs are produced in the grid element under consideration; the required normalized specific activity levels are taken from the external data libraries of COSYMA.

The exponential factor RD accounts for the radioactive decay during an initial delay between the production and consumption of a foodstuff. For each foodstuff, the user can specify the delay times to be taken into account for banning with the NAMELIST variable FBDLAY.²

The intervention levels depend on the nuclide group and on the foodstuff. The number of the nuclide groups and of the radionuclides belonging to each group is defined with the NAMELIST variables IFBNUU, CFBNUK, IFBNID, and CFBNI2 or CFBNI8 (with CFBNI2, all isotopes of a chemical element can be selected, with CFBNI8 individual radionuclides).

In order to avoid the tedious task to specify an intervention level for each individual foodstuff and nuclide group, foodstuffs can be combined to foodgroups in the sense, that the same intervention level is assigned to all foodstuffs belonging to the group. However, this grouping of foodstuffs can only be done once and it is thus not possible to specify different foodgroups for different nuclide groups. - The number of the foodgroups and the foodstuffs belonging to each group is defined with the NAMELIST variables IFBNF1, IFBF01 and CFBF01. The intervention levels for all the possible combinations of nuclide and foodgroups are specified with the NAMELIST variables FBILIA (introduction of bans) and FBILWA (withdrawal of bans).

Since all foodstuffs are compared individually with the intervention levels, all foodstuffs get individual foodban flags, even if they belong to the same foodgroup. An overlay of different foodban flags can be achieved with the post-IL-processing variables IFBNF2 and IFBF02. Variable IFBNF2 specifies how many different values for IFBF02 exist, i.e. for each foodstuff, IFBF02 can have a value between 1 and IFBNF2. Variable IFBF02 specifies which foodstuffs belong together, and all foodstuffs with the same value for IFBF02 will get the most restrictive ban flag found for any of them.

² The values of FBDLAY are used only inside the foodban module and are in general different from the values of FDELAY assumed for the calculations of doses and risks described in Chapter " 4. Doses and risks from ingestion"

Algorithm

$$R(N, f, t, g) = \frac{AF(N, f, t, g)}{IL(N, F)} \left\{ \begin{array}{l} \geq 1 \text{ for any } N: \text{ foodban} = \text{YES for } f \\ < 1 \text{ for all } N: \text{ foodban} = \text{NO for } f \end{array} \right\}$$

with

$$AF(N, f, t, g) = \sum_{n \in N} AF(n, f, t, g)$$

and

$$AF(n, f, t, g) = RD(n, f) \times AFG(n, f, t) \times AG(n, g)$$

where

F foodgroup for banning (F = 1, 2, ..., IFBNF1)

f foodstuff belonging to group F

g grid element

N nuclide group for banning (N = 1, 2, ..., IFBNNU)

n radionuclide belonging to group N

t time

AF activity-in-food per unit amount of foodstuff [Bq/kg]

AFG as above, but normalized to unit initial deposit [(Bq/kg)/(Bq/m²)]

AG total activity initially deposited on ground [Bq/m²]

IL intervention level [Bq/kg]

RD reduction factor to take account of the radioactive decay during a delay between production and consumption of the foodstuff:

$$RD(n, f) = \exp - (\lambda_r(n) \text{ FBDLAY}(f))$$

NAMELIST variables (for details see COSYMA USER GUIDE)

Delays between harvest and consumption for foodbans: FBDLAY(1...NFOO)

Definition of N: IFBNNU CFBNUK(1...IFBNNU)

IFBNID(1...IFBNNU) CFBNI#(1...IFBNID, 1...IFBNNU)

Definition of F: IFBNF1 IFBFO1(1...NFOO) CFBFO1(1...IFBNF1)

Intervention levels (introduction): FBILIA(1...IFBNNU, 1...IFBNF1)

Intervention levels (withdrawal) : FBILWA(1...IFBNNU, 1...IFBNF1)

Post-IL-processing: IFBNF2 IFBFO2(1...NFOO)

Table 2. CFBANS = ALEV - Algorithm and NAMELIST variables

3.1.3 Foodbans assumed to be based on individual doses

The model for evaluating foodbans under the assumption of intervention levels based on individual doses is selected with the option CFBANS = DOSE of input group RESULTS. Table 3 on page 3-6 summarizes the foodban algorithm and the NAMELIST variables which influence the calculations.

For a given foodgroup, organ doses resulting from the consumption of all foodstuffs belonging to the group are calculated. The 'foodban on' condition is met for all foodstuffs belonging to the group if the corresponding intervention level is exceeded for any of the organs, and the 'foodban off' condition if the intervention levels are not exceeded for any of the organs.

The doses are calculated under the assumption that the foodstuffs are produced in the grid element under consideration. The required age-dependent dose conversion factors and the time-integrated normalized activity concentrations in food are taken from the external data libraries of COSYMA.

If the dose intervention levels are assumed to apply to the average rather than the critical group, initial delays between harvest and consumption can be specified for each foodstuff with the NAMELIST variable FBDLAY; these delays are additional to those already taken into account in the normalized activity levels in food data.

The intervention levels depend on the organs and on the foodgroups. The organs to be considered for banning are selected from the organs available in COSYMA with the NAMELIST variables IFBNOG and IFBORG.

The number of the foodgroups and the foodstuffs belonging to the groups are defined with the NAMELIST variables IFBNF1, IFBFO1 and CFBFO1. As it is for CFBANS = ALEV, the grouping of foodstuffs can only be done once and it is not possible to specify different foodgroups for different organs. It is also not possible to assign one foodstuff to more than one foodgroup (example: it is not allowed to consider the milk consumption of babies and then use milk again as a part of an average foodbasket for adult consumers). The intervention levels for all the possible combinations of foodgroups and organs are specified with the NAMELIST variables FBILID (introduction of bans) and FBILWD (withdrawal of bans).

For each foodstuff, a consumption rate and the assumed age of the consumer are defined with the NAMELIST variables FBCRAT³ and IFBAGE. Care has to be taken to specify the same consumer age for all foodstuffs belonging to the same foodgroup, since this is not checked in the code.

Because of the way the foodban flags are calculated, all foodstuffs belonging to the same foodgroup get identical banflags. An additional overlay of different foodban flags can be achieved with the variables IFBNF2 and IFBFO2 in the same way as described in the previous section.

³ The values of FBDLAY and FBCRAT are used only inside the foodban module and are in general different from the values of FDELAY and FCRATE assumed for the calculations of doses and risks described in Chapter " 4. Doses and risks from ingestion".

Algorithm

$$R(o, F, t, g) = \frac{D_a(o, F, t, g)}{IL(o, F)} \left\{ \begin{array}{l} \geq 1 \text{ for any } o: \text{ foodban} = \text{YES for } F \\ < 1 \text{ for all } o: \text{ foodban} = \text{NO for } F \end{array} \right\}$$

with

$$D_a(o, F, t, g) = \sum_{f \in F} DF_a(o, f, t, g)$$

and

$$DF_a(o, f, t, g) = \sum_n AG(n, g) \times RD(n, f) \times AFY(n, f, t) \times FCR(f, a) \times DCF(n, o, a)$$

where

a age group of consumer
F foodgroup for banning ($F = 1, 2, \dots, IFBNF1$)
f foodstuff belonging to group F
g grid element
n radionuclide
o organ to be considered for banning
t time

AFY yearly time integral of activity in foodstuff per unit amount of foodstuff normalized to unit initial deposit $[(a \cdot \text{Bq/kg}) / (\text{Bq/m}^2)]$
AG total activity initially deposited on ground $[\text{Bq/m}^2]$
DCF dose conversion factor (integrated 50 a after single intake) $[\text{Sv/Bq}]$
FCR food consumption rate $[\text{kg/a}]$
IL intervention level $[\text{Sv}]$

RD reduction factor to take account of the radioactive decay during a delay between production and consumption of the foodstuff:

$$RD(n, f) = \exp - (\lambda_T(n) \text{ FBDLAY}(f))$$

NAMELIST variables (for details see COSYMA USER GUIDE)

Delays between harvest and consumption for foodbans: FBDLAY(1...NFOO)

Definition of F: IFBNF1 IFBFO1(1...NFOO) CFBFO1(1...IFBNF1)

Consumer age and consumption rates: IFBAGE(1...NFOO) FBCRAT(1...NFOO)

Selection of organs: IFBNOG IFBORG(1...NORG)

Intervention levels (introduction): FBILIA(1...IFBNOG, 1...IFBNF1)

Intervention levels (withdrawal) : FBILWA(1...IFBNOG, 1...IFBNF1)

Post-IL-processing: IFBNF2 IFBFO2(1...NFOO)

Table 3. CFBANS = DOSE - Algorithm and NAMELIST variables

3.2 DURATION OF FOODBANS AND FOODBAN FLAGS

3.2.1 General features

In COSYMA, it is always assumed, that foodbans, if any, are introduced at the time of the accident and last for the longest possible time. That means, if a series of 'ban on / ban off' conditions is encountered for a given foodstuff, the first 'ban off' after the last 'ban on' determines the duration of the foodbans.

The 'ban on' or 'ban off' condition is checked for in the way described in the previous chapters at a number of discrete times after the accident. Because of this, a decision about the bans between two time points is impossible, and the time resolution of the ban duration is determined by the lengths of the intervals between the different time points.

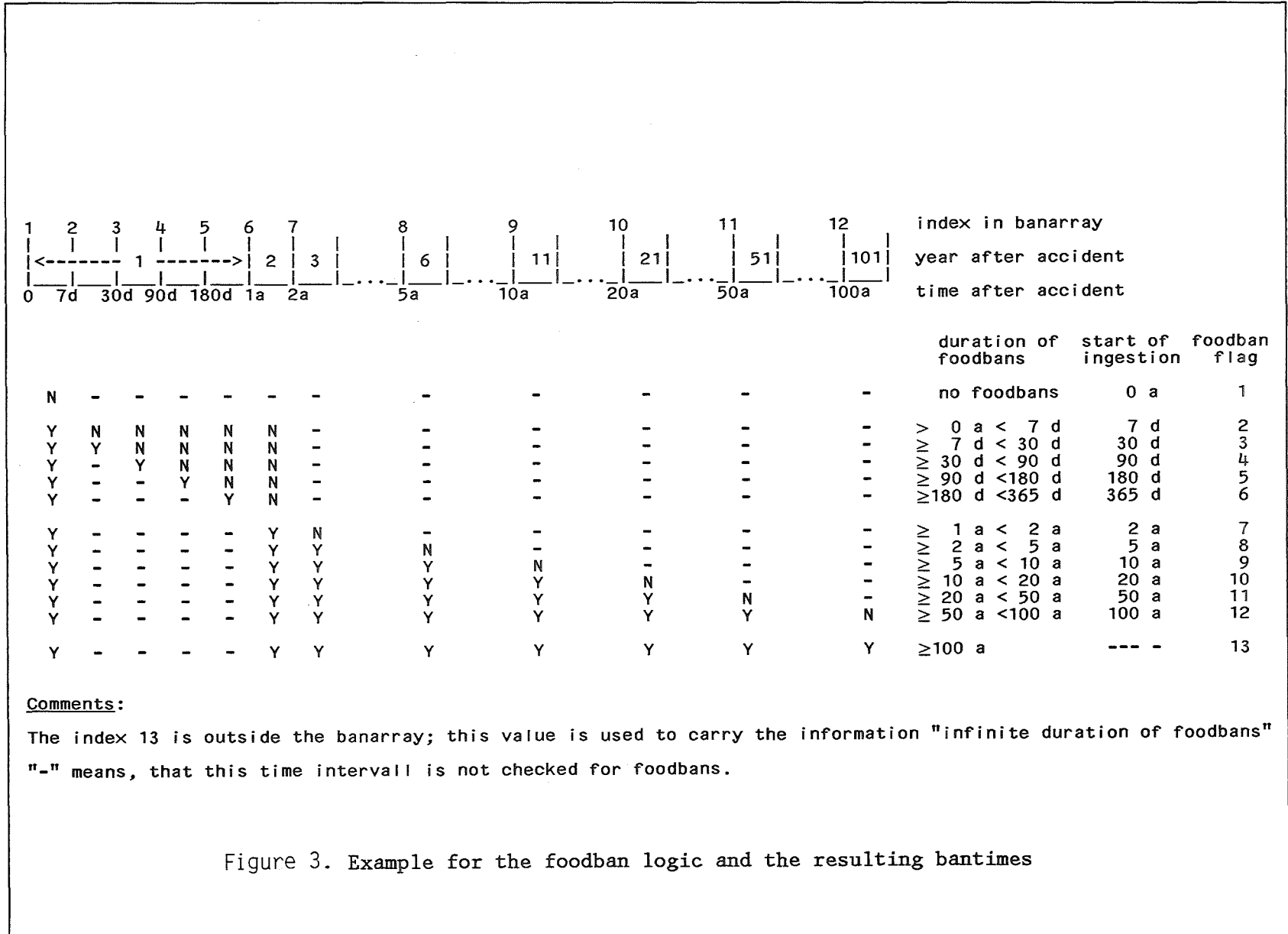
The total number NBAN of time points and the corresponding times (also referred to as the "banarray") are fixed by the time parameterization of the normalized specific activity levels in food required for the calculations. The actual values depend on the foodchain transport model which generated the data and are included in the foodchain data files.

The outcome of the tests for foodbans at the different times determine the assumed duration of the foodbans. The foodban flags contain the resulting starting times of ingestion in the form of the corresponding index in the banarray. A flag value of 1 always indicates the absence of foodbans, and values between 2 and NBAN occur for finite ban durations; an infinite duration of the bans is represented by the value of NBAN+1.

An example is given in Figure 3 on page 3-8 for a banarray with 12 times, which are shown on top. Below, all foodban durations possible with this banarray and the corresponding foodban flags are listed. With the given banarray, the time resolution for the foodbans is relatively fine in the first year after the accident and gets broader as time goes on. Since NBAN = 12 in the example, the condition 'infinite ban duration' leads to a foodban flag value of 13.

On exit of the foodban algorithm, the foodban flags correspond to the intermediate flags in Figure 2 on page 3-2; they may be modified by the post-IL-processing procedure.⁴

⁴ The parameterization of the relocation times does in general not match the times in the ingestion banarray. In the cases when the relocation time exceeds the estimated foodban duration, the index corresponding to the time in the banarray which exceeds the relocation time is assigned to the foodban flag.



3.2.2 Algorithm

The algorithm for calculating the foodbans in COSYMA must meet three basic requirements:

- The computing times should be moderate.
- It must be able to operate with banarrays of different lengths and time values.
- In the cases of a series of ban on / ban off conditions for a given foodstuff, it must find the maximum ban time.

The first two constraints lead to a relatively straightforward structure of the algorithm, in which all foodstuffs are treated equal and the number of conditional branches is small. The third constraint led to a special data structure for the test quantities which determine the decision about the foodbans (CFBANS=ALEV: activity levels in food; CFBANS=DOSE: committed doses from yearly intake).

Figure 3 may serve to illustrate the different steps of the calculations. The procedure is applicable for the ALEV model as well as for the DOSE model, only the test quantities are different:

Step 1 - Test for foodbans at $T = 0$ with the ILs for 'introduction'

If the 'foodbans = NO' condition is found, it is assumed that no foodbans are necessary, and no further tests are made. If the 'foodbans = YES' condition is found, the outcome of the tests performed in Steps 2 and 3 determine the duration of the foodbans.

Step 2 - Test for foodbans at $T = 1$ a with the ILs for 'withdrawal'

The outcome of this test acts again as a switch: If the 'foodbans = NO' condition is met, only the times smaller than one year will be examined for foodbans -> Step 3a. If the 'foodbans = YES' condition is met, only the times greater than one year will be examined -> Step 3b.

Step 3a (downward search) - Test for foodbans at times $T < 1$ a

These tests are performed with the intervention levels for introduction. Starting with the next smaller time than one year in the banarray, it goes backward in time until the first time the 'foodbans = YES' condition is found. The value of the foodban flag is the index corresponding to the last time the 'foodbans = NO' condition was met.

Step 3b (upward search) - Test for foodbans at times $T > 1$ a

Starting with the next greater time than one year in the banarray and going forward in time, these tests are performed using the intervention levels for withdrawal. The ingestion is assumed to begin at the first time the 'foodbans = NO' condition is found, and the value of the foodban flag is the corresponding index in the banarray. - If the 'foodbans = YES' condition is met for the last time in the banarray, an infinite duration of foodbans is assumed and the value of the foodban flag is set to NBAN+1.

For proper operation, and especially for the third constraint mentioned initially, the algorithm requires that the values of the test quantities are decreasing with time. However, this is not necessarily true for all foodstuffs and assumed release dates. Therefore, two modifications are made to the normalized activity-in-food data:

1. When creating the **data files** containing A(T) and D(T,T+1a), the data for T = 0 are artificially set to the maximum value found for any of the times in the banarray (essential for Step 1).
2. In the **code**, the index IBAMAX of the highest position in the banarray containing the maximum value is determined. If IBAMAX is greater 1, all values for the indices 2 ... IBAMAX are replaced by the maximum value. This ensures that in Step 3 always the maximum ban duration is found. (The corresponding manipulations of the data are done at runtime in the setup phase and not in the algorithm phase).

To use the intervention level for ban introduction in Step 3a (i.e. for times smaller than one year) is not cogent. However, experience with COSYMA has shown, that the foodban durations calculated with the intervention levels for withdrawal in the backward search mode can be difficult to interpret (although formally correct), if the intervention levels for withdrawal are significantly lower than those for introduction. Moreover, in the "real world" it does not seem to make much sense to apply one intervention level for introduction and a different one only, say, 30 days later.

3.3 AREAS AND AMOUNTS OF PRODUCE AFFECTED BY FOODBANS

As a measure of the economic impact of foodbans, COSYMA provides information about the probabilities as a function of time for the following quantities:

1. **Potential area:** This is the area in terms of km² of all grid elements which are estimated to be affected by foodbans.
2. **Annual produce:** This is the amount in terms of litres of milk, number of livestock or kilograms of crop normally produced in one year in the potential area.
3. **Crop area:** This is the part of the potential area, where crop is normally produced.

For the estimation of the last two quantities, gridded data are required for the agricultural production as well as for human consumption (Level 3) as for economics (Level 4).

If such information is missing, the potential area is the only quantity which can be calculated; it allows to give an upper limit for the economic impact under the assumption, that the area affected by foodbans is used entirely for the purpose of agricultural production. Since by default the program assumes, that Level 3 and Level 4 data grids are attached at runtime if foodbans are to be considered in the calculations, their absence must be indicated with the NAMELIST variables CIGRL3 (Level 3) and CIGRL4 (Level 4) of input group RESULTS.

4. DOSES AND RISKS FROM INGESTION

4.1 GENERAL FEATURES

COSYMA provides two options for the evaluations of doses and risks from ingestion:

1. With the first option, the results are calculated under the assumption, that all food consumed is produced at the point of consumption, and that the required amount of food is produced in each grid element (local production and consumption approach; abbreviated L-P&C). This model is selected by specifying CIGCOL = L-P&C in input group RESULTS.
2. With the second option, the results are calculated under the assumption that all contaminated food produced is consumed somewhere (agricultural production approach, abbreviated APROD); this model is selected with CIGCOL = APROD. These calculations require data files containing information about the agricultural production used for human consumption in the grid elements.

The table below summarizes the results calculated by COSYMA in both cases:

<p>CIGCOL = L-P&C Individual and collective doses calculated from individual intake. Individual and collective risks calculated with activity-risk coefficients.</p> <p>CIGCOL = APROD No individual doses or risks. Collective doses and risks calculated with agricultural production data.</p>

Table 4. Options for the calculations of ingestion doses and risks

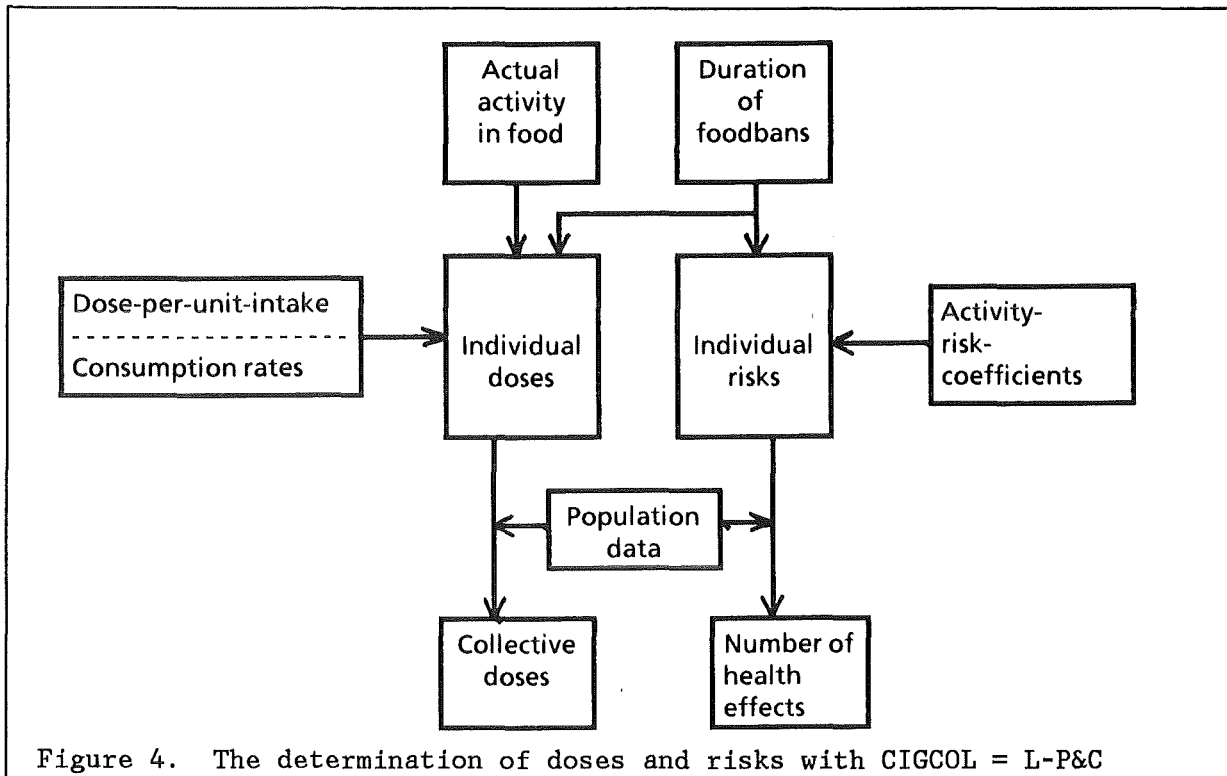
The concept of "activity-risk coefficients" (ARCs) for the calculation of risks of radiation-induced fatal stochastic somatic health effects has been developed at KfK to calculate the number of late health effects as a function of time after the accident; the application of this formalism on the ingestion pathways is described in [2].

With the ARCs, the individual and collective risk can be estimated as a function of time. However, for ingestion, the method implies the assumption of local production and consumption of the foodstuffs, which will give a rather crude approximation of the activity intake both of individuals and in the general population for many foodstuffs and accident scenarios.

On the other hand, the agricultural production method will in general give a more accurate estimate of the total activity intake in the population, but the risk assessment is rather crude, because such effects as for example the age structure of the population and the aging of the affected individuals can only be taken into account on the average. A further disadvantage is the lack of information on the ranges of individual doses and risks which make up the collective doses and risks; hence, individual doses and risks are not calculated in the "APROD" mode.

4.2 LOCAL PRODUCTION AND CONSUMPTION APPROACH

The principles of the calculations of the individual and collective ingestion doses and risks are illustrated in Figure 4:



In the L-P&C-mode, COSYMA calculates the individual ingestion doses from the individual activity intake estimated with consumption rates, and the individual risks using the activity-risk coefficients without an intermediate dose assessment step. The corresponding collective quantities are obtained from the individual ones using population data.

Table 5 lists the algorithms and the NAMELIST variables influencing the calculations of the individual doses and risks.

4.2.1 Individual and collective doses

For each foodstuff, the **individual dose** in each grid element is obtained by multiplication of the activity initially deposited, the radionuclide concentration in the foodstuff normalized to unit initial deposit, the consumption rate, and a dose conversion factor (see Table 5). The **collective dose** is obtained by multiplying the individual dose with the number of individuals in the grid element taken from the COSYMA population data grid and summing up the contributions from all grid elements.

The doses are calculated for an average adult member of the population; the consumption rates are defined with the NAMELIST variable FCRATE. The required dose-per-unit-intake data for adults and the time-integrated normalized activity concentrations in food are taken from the external data libraries of COSYMA.

Algorithms

$$ID(n, o, f, g) = AG(n, g) \times RD(n, f) \times AFI(n, f, t_b(f), t_d) \times FCR(f) \times DCF(n, o)$$

$$IR(n, o, f, g) = AG(n, g) \times RD(n, f) \times ARC(n, o, f, t_b(f), t_r)$$

where

f;g foodstuff; grid element
n;o radionuclide considered for ingestion; organ or health effect
tb time of start of ingestion (given by the foodban flag)
td time of end of activity intake for dose calculations ($td=t(IZINT)^1$)
tr integration time for ARCS

ID individual dose for adults from ingestion of foodstuff f between time tb and time td [Sv]²)

IR cumulative individual risk for an individual representing the average population at time tr after the accident resulting from ingestion between time tb and time tr²)

AFI time integral from tb to td of activity in foodstuff per unit amount of foodstuff normalized to unit initial deposit [$(a \cdot Bq/kg)/(Bq/m^2)$]

AG total activity initially deposited on ground [Bq/m^2]

ARC activity-risk coefficient normalized to unit deposit [$1/(Bq/m^2)$]

DCF dose conversion factor (integrated 50 a after single intake) [Sv/Bq]

FCR food consumption rate for adults [kg/a]

RD a reduction factor to take account of the radioactive decay during possible delays between harvest and consumption of each foodstuff f, which can be assumed to be consumed in two forms "FR" and "PR", each with a different delay time ($FFRACT(f) + PFRAC(f) = 1$):

$$RD(n, f) = [FFRACT(f) \exp - (\lambda_r(n) FDELAY(f))] + [PFRAC(f) \exp - (\lambda_r(n) PDELAY(f))]$$

NAMelist variables (for details see COSYMA USER GUIDE)

Consumption rates: FCRATE(1...NFOO)

Delays and fractions: FFRACT(1...NFOO) FDELAY(1...NFOO) PDELAY(1...NFOO)

Notes

- ¹) The value of td is defined with the variable IZINT in the input group DOSRISK of COSYMA.
- ²) If Level 2 \neq Level 1, the results are parametrized with respect to the Level 2 foodstuffs in the following way (F2 = Level 2 food category; f = Level 1 foodstuff belonging to category F2):

$$\bar{ID}(n, o, F2, g) = \sum_{f \in F2} ID(n, o, f, g) \quad \text{and} \quad \bar{IR}(n, o, F2, g) = \sum_{f \in F2} IR(n, o, f, g)$$

Table 5. CIGCOL = L-P&C - Algorithms and NAMelist variables

The exponential factor RD accounts for the radioactive decay during an initial delay between the production and consumption of a foodstuff additional to the initial delay already accounted for in the specific activity concentrations in food data. Each foodstuff can be assumed to be consumed in two forms with different delay times. The one with the shorter delay is referred to as the "fresh product (FR)", the one with the longer delay as the "processed product (PR)". The two delay times are defined with the NAMELIST variables FDELAY and PDELAY, respectively, and the fraction of the consumption of the "FR" form to the total consumption of the foodstuff is given with variable FFRACT (PFRACT is taken to be 1. - FFRACT in the code).

4.2.2 Individual and collective risks

With the ARC method, the **individual risk** in each grid element is obtained simply by multiplication of the appropriate ARC with the amount of activity initially deposited (see Table 5; the exponential factor RD is the same as for the dose calculations). The **collective risk** is obtained by multiplying the individual risk with the number of individuals in the grid element taken from the COSYMA population data grid and summing up the contributions from all grid elements.

Values of the activity-risk coefficients per unit deposit are precalculated for a series of foodban times after the accident and stored in data files. The risk of cancer allowing for e.g. foodbans of a duration of one year is calculated using the ARC in which ingestion is assumed to start one year after the accident.

The calculation of the activity-risk coefficients for ingestion requires data about the age- and life expectancy distributions in the population, time dependent concentrations of radioactivity in food normalized to unit initial deposit, age dependent consumption rates, time- and age-dependent dose conversion factors, and risk coefficients.

The data used to calculate the activity-risk coefficients files supplied with the COSYMA program package are given in the USER GUIDE. If the user wants to change any of these data, new ARC data sets must be generated. For this task, several of the COSING preprocessors are required, which can be made available on request.

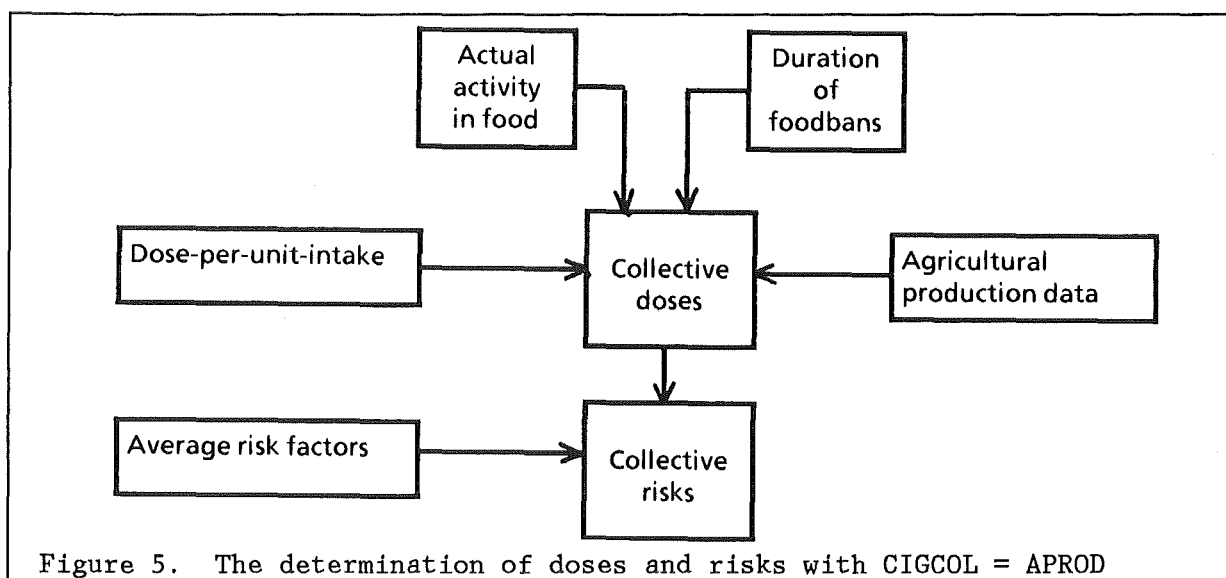
4.3 AGRICULTURAL PRODUCTION APPROACH

With this method, only the **collective** doses and risks can be evaluated, and the collective risks are calculated from the collective doses.

The flow of the calculations and the required data are shown in Figure 5; the algorithms and the NAMELIST variables are given in Table 6 on page 4-6.

4.3.1 Collective doses

The collective dose in each grid element is estimated from the amount of activity initially deposited, the radionuclide concentrations in the foodstuffs normalized to unit deposit, the annual agricultural produce used for



human consumption in the grid element taken from the agricultural production data grids of COSYMA, and a dose conversion factor. The calculations are carried out for average adult members of the population using the dose-per-unit-intake data described in the previous chapter.

As in the local production and consumption approach, each Level 1 foodstuff can be assumed to be consumed in two forms with shorter (SP) and longer (PR) delay times, which are specified with the NAMELIST variables FDELAY and PDELAY; the fraction of the consumption of the "FR" form to the total consumption of the foodstuff is given with variable FFRACT.

However, in contrast to the L-P&C-approach, the influence of these parameters on the calculations depends on the agricultural production data⁵ :

- If, for a given Level 1 foodstuff, which determines the activity levels in food, production data for both the FR and PR forms are available, the fraction FFRACT is ignored, since it is given by the corresponding data, and the delay times are applied separately to the FR and PR production data (Algorithm A1).
- If there is only one production item for a Level 1 foodstuff, an average factor is applied to account for the two delay times (Algorithm A2).

The NAMELIST variable FHUMAN, with which the annual agricultural produce is multiplied, can be used for a modification of the production data. If, for instance, grid data are available only for the total amounts produced for human consumption as well as for animal fodder or other purposes, FHUMAN allows to take account of this fact at least on the average by specification of an appropriate reduction factor.

⁵ In the CIGCOL = APROD mode, the code examines for each Level 1 foodstuff the content of the pointer array L1L3PR to decide which of the two algorithms is to be used: if PR points to a Level 3 foodstuff category, algorithm A1 is used, if it is zero, algorithm A2.

4.3.2 Collective risks

The estimation of the number of fatal stochastic somatic health effects with the production approach makes use of the assumption of a linear dose-response-relationship, which means that the total incidence of health effects in an exposed population is related to the collective dose. Therefore, the number of the health effects under consideration is calculated by multiplication of the collective dose derived in the way described above with a risk factor averaged over the whole population. The current default values for the average risk factors are given in the USER GUIDE.

Algorithms

Collective dose:

A1 - On Level 3, two items "FR" and "PR" for a Level 1 foodstuff f:

$$CD(n, o, f, g) = \frac{AG(n, g) \times AFI(f, n, t_b, t_e) \times [RF(n, f) FRPROD' + RP(n, f) PRPROD'] \times DCF(n, o)}{}$$

A2 - Level 3 foodstuff corresponds to Level 1 foodstuff f:

$$CD(n, o, f, g) = AG(n, g) \times AFI(f, n, t_b, t_e) \times RD(n, f) \times PROD' \times DCF(n, o)$$

with

$$\begin{aligned} PROD' &= FHUMAN(PROD) \times PROD \\ FRPROD' &= FHUMAN(FRPROD) \times FRPROD \\ PRPROD' &= FHUMAN(PRPROD) \times PRPROD \end{aligned}$$

Collective risk:

$$CR(n, o, f, g) = CD(n, o, f, g) \times \overline{RCF}(o)$$

Table 6. CIGCOL = APROD - Algorithms and NAMELIST variables

where

f Level 1 foodstuff
g grid element
n radionuclide
o organ or health effect
tb time of start of ingestion (given by the foodban flag)
td time of end of activity intake for dose calculations ($td=t(IZINT)^1$)

CD collective dose [Sv], which would result if the agricultural produce is consumed from time tb to time td by a population made up of adult individuals

CR collective risk

AFI time integral from tb to td of activity in foodstuff per unit amount of foodstuff normalized to unit initial deposit $[(a*Bq/kg)/(Bq/m^2)]$
AG total activity initially deposited on ground $[Bq/m^2]$
DCF dose conversion factor (integrated 50 a after single intake) [Sv/Bq]
RCF risk factor for health effect o averaged over the population [1/Sv]

PROD annual production of Level 3 foodstuff in grid element ([kg/a] or [l/a])

RD, reduction factors to take account of the radioactive decay during a
RF, delay between production and consumption of the foodstuff (FFRACT +
RP PFRACT = 1):

$$RD(n, f) = [FFRACT(f) \exp - (\lambda_r(n) FDELAY(f))] + [PFRACT(f) \exp - (\lambda_r(n) PDELAY(f))]$$
$$RF(n, f) = \exp - (\lambda_r(n) FDELAY(f))$$
$$RP(n, f) = \exp - (\lambda_r(n) PDELAY(f))$$

NAMELIST variables (for details see COSYMA USER GUIDE)

Fraction of fresh product: FFRACT(1...NFOO)
Delays (fresh and processed): FDELAY(1...NFOO) PDELAY(1...NFOO)
Fraction used for human consumption: FHUMAN(1...NAPR)

Note

¹⁾ The value of td is defined with the variable IZINT in the input group DOSRISK of COSYMA.

Table 6. CIGCOL = APROD - Algorithms and NAMELIST variables (continuation)

5. REFERENCES

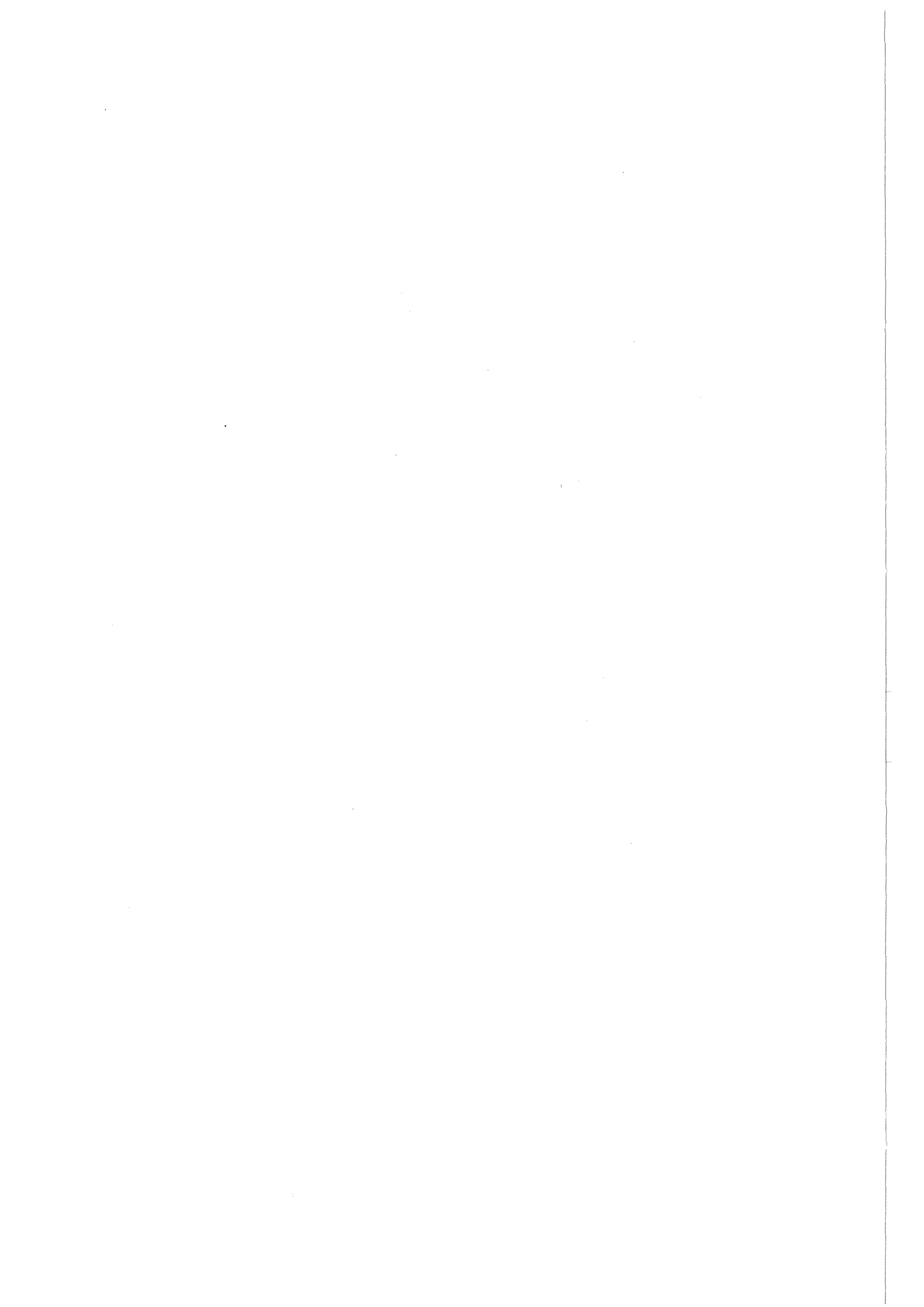
- [1] COSYMA: User guide. Compiled by I. Hasemann and J.A. Jones. Brussels and Karlsruhe, Report EUR 13045/KfK-4331B (1991).
- [2] J. EHRHARDT, C. MATZERATH, C. STEINHAUER. Method for calculating time dependent individual and collective cancer risks in the accident consequence assessment code UFOMOD. In: Proceedings of the joint OECD (NEA)/CEC Workshop on "Recent Advances in Reactor Accident Consequence Assessment", Rome, Italy, January 25-29, p. 278-288 (1988).

Part III

The default ingestion data of the COSYMA program package

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1. OVERVIEW

Table 1 shows the default ingestion data which are used in connection with the program package of COSYMA (version 91/1). Several additional files for special applications are available on request. An actual list of all available data libraries can be found in chapter "Input group INGESTI" in Part III and PART IV of the COSYMA USER GUIDE [1].

Classification of data -----	Type code -----	Implemented -----
Activity-in-food	IG-91/AX ¹⁾	COSYMA-91/1
Dose conversion	NRPDCF91 ²⁾	COSYMA-91/1
Risk conversion	GSFRCF88 ³⁾	COSYMA-91/1
Consumption rates	91/1	COSYMA-91/1
Agricultural production	91/1	COSYMA-91/1

Notes:

¹⁾ Character 17 to 24 of the data file identifier
²⁾ Character 65 to 72 of the data file identifier
³⁾ Character 73 to 80 of the data file identifier

Table 1. COSYMA-91/1: Default ingestion data provided with the program package

The data for activity-in-food and for dose- and risk conversion are characterized by a type code, which is a part of the file identifier and serves to distinguish between different versions of the data. The file identifier is contained as the first record in the corresponding files and printed out when a file is addressed by COSYMA. With this, the user has the possibility to check if a file attached at runtime actually refers to the desired version of the data.

The implementation specification in Table 1 refers to the version number of COSYMA the data were implemented in. Until further notice, they will also be used in the successor versions. Since there is no corresponding type code for the consumption rates and the agricultural production grids, these data are distinguished by the implementation specification.

1.1 REFERENCES

- [1] COSYMA: User guide. Compiled by I. Hasemann and J.A. Jones. Brussels and Karlsruhe, Report EUR 13045/KfK-4331B (1991).

2. THE ACTIVITY-IN-FOOD DATA IG-91/AX AND IG-90/BX

2.1 INTRODUCTION

A recent study of the National Radiological Protection Board (NRPB, UK) and the GSF - Forschungszentrum für Umwelt und Gesundheit (FRG) resulted in a general terrestrial foodchain transport model intended for use in the EC where site specific information is not available [1]. It was concluded, that this model is for instance appropriate for probabilistic accident consequence assessment (ACA) codes, which deal with a range of meteorological conditions and radiological consequences over large areas.

Two dynamic foodchain models, FARMLAND (Food Activity from Radionuclide Movement on Land) developed at NRPB [2], [3], [4], and ECOSYS developed at GSF [5], formed the basis of the study [1]. For COSYMA, the model FARMLAND was used with the parameters derived for the general EC-model for the description of the transport of radionuclides through the terrestrial foodchains and the agricultural practices to generate the default activity-in-food files with the designation IG-91/AX.

These files replace the former default data IG-DEF-90/A1 [6], [7], which were based on results calculated for average German agricultural conditions with a version of ECOSYS [8], [9], which was a predecessor of the model ECOSYS referred to in [1].

By technical reasons, the old IG-DEF-90/A1 data are now obsolete and can no longer be used in connection with COSYMA-91/1. In addition, they do no longer represent the "state of the art" of the foodchain modelling with ECOSYS. However, for the sake of a comparison between accident consequence assessment results obtained with the old ECOSYS and the new FARMLAND default data, a modified version of IG-DEF-90/A1, which can be used with COSYMA-91/1, was generated. These data have the type code IG-90/BX and are available on request. The differences between the IG-DEF-90/A1 and the IG-90/BX files are explained in the first section of this chapter.

The second section deals with the features of the foodchain transport model data which are relevant with respect to their application in COSYMA, and outlines the differences between IG-91/AX and IG-90/BX under this point of view. This may be especially of interest for users which are familiar with the old default data and now switch over to the new ones. The third section gives time-integrated normalized activity concentrations in food and effective dose equivalents for isotopes of strontium, iodine and cesium, which can be of help for the interpretation of differences in the ACA-results with the old and the new data and also for hand-calculations of radiological consequences from ingestion.

2.2 DIFFERENCES BETWEEN THE ECOSYS FILES IG-90/BX AND IG-DEF-90/A1

Due to changes in the file structure and in the foodban algorithm, it became necessary to replace the former ECOSYS files named IG-DEF-90/A1 by the new versions IG-90/BX, which are adapted to the use in connection with COSYMA-91/1.

There are two basic differences between the old and the new files:

1. The dummy data for sheep and for foodban times < 1 a, which had been introduced into IG-DEF-90/A1 for testing purposes, were removed.
2. Due to problems in the old foodban part of the code, IG-DEF-90/A1 did not contain the original data calculated by ECOSYS, but data which were modified with respect to the time dependence, although the total time integral was maintained (see [6], Part IV.A). This is now no longer necessary and also not compatible with the other ingestion data files available with COSYMA, and the new ECOSYS files IG-90/BX do in fact represent the original ECOSYS data provided by GSF.

The first change influences only the data structure, since the dummy data were all zero anyway.

The second change affects the time dependence of the data, especially in the first two years after the accident, but not the total time integrals. As a consequence, all potential ingestion results, i.e. those calculated without foodbans, are still the same, because here only the total intake is relevant. However, as soon as foodbans come into effect, the time patterns of the data matter and differences in the results obtained with the old and new data will occur.

2.3 DIFFERENCES BETWEEN THE IG-90/AX- AND THE IG-90/BX DATA

Table 2 summarises the basic differences between the FARMLAND IG-91/AX- and the ECOSYS IG-90/BX data:

	IG-91/AX -----	IG-90/BX -----
activity levels in food	yes	no
time-integrated activity levels in food	yes	yes
foodban times smaller than one year	yes	no
data for pork	- see text -	yes
data for sheep meat	yes	no
vegetables grown all year	yes	no
data for liver	yes	no
ingrowth of Am-241 from Pu-241 after deposition	no	yes
initial delays accounted for in data	no	yes

Table 2. IG-91/AX, IG-90/BX: Different features of the data

The absence of activity-in-food data and of data for foodban times smaller than one year¹⁾ in the old ECOSYS data has historical reasons; since the former are required for the calculations of foodbans with intervention levels assumed to be based on activity levels in food, the option CFBANS=ALEV cannot be used in connection with IG-90/BX.

The original FARMLAND files did not contain data for pork. This was felt to be unsatisfactory for COSYMA, since pork is a major foodstuff in most of the EC countries (see, for instance, [10]). Therefore, the pork data from IG-90/BX were added to the FARMLAND data to allow the consideration of pork in ACA assessments with the default ingestion data files of COSYMA. In the default setup for IG-91/AX, "PORK" is marked active for the calculations. If the user wants assessments without pork, it can be switched off by setting the NAMELIST variable L1L2(pork) to zero.

Since the parameterization of the pork data from IG-90/BX is different to the data from FARMLAND, there are some peculiarities with respect to the NAMELIST input concerning foodbans:

- There are no activity concentrations for pork, so that foodban flags for pork cannot be obtained directly in the foodban module when the option CFBANS = ALEV is active. As an approximation, they are taken over from some other appropriate foodstuff. This is accounted for in the default setup for IG-91/AX (see COSYMA USER GUIDE [11] for details). - For calculations with CFBANS = DOSE, only the time integrated activity concentrations are required, and no special procedure is necessary.
- If foodban flags are assigned to pork which are taken over from other foodstuffs, either by the reason mentioned above or by some other reason, they can refer to bantimes smaller than one year, for which no pork data exist. This is taken account of in the IG-91/AX data files by insertion of the values for one year for the missing data, i.e. bantimes < 1 a for pork are treated as a foodban of one year duration in the calculations.

IG-91/AX gives data for green vegetables, which can be considered to represent some average over the categories "leafy vegetables", i.e. all vegetables from which the leaves are consumed, and "non-leafy vegetables", i.e. tomatoes, cucumber etc., whereas IG-90/BX gives data separately for the two vegetable types. With respect to the agricultural production model, the green vegetables from FARMLAND are assumed to be produced and consumed all year round, whereas a fallow period in the winter season is assumed for the leafy- and non-leafy vegetables from ECOSYS. This difference especially shows up in the contamination of the vegetables by radionuclides with a short radioactive half life (e.g. I-131) after a release in winter, which can be significant for green vegetables, but is negligible for leafy- and non-leafy vegetables because of the radioactive decay in the time span between the deposition and the begin of the growth period.

Data for liver and for Am-241 from ingrowth of Pu-241 after deposition become relevant only for releases which contain significant fractions of actinides; unfortunately, the availability of both is mutually exclusive in the two data files. At present, there is insufficient experience with such source terms in

¹⁾ This applies only to IG-90/BX; the data for the activation products from fusion reactors in IG-91/BX are also calculated with ECOSYS, but do contain both features.

COSYMA to judge which of the two aspects is more significant with respect to ingestion-related ACA results.

Some of the NAMELIST variables in input group INGESTI, which influence the outcome of ingestion related calculations with COSYMA and can be altered by the user, depend on the foodstuffs available in the ingestion data, or on the initial delays already accounted for in the data. These parameters must thus be known in order to produce sensible results. Other parameters cannot be changed by the user, but their knowledge may be helpful in interpreting the results of the assessments, as, for example, the available foodban times or the factors assumed in the foodchain models to account for the preparation losses. Table 3 shows the parameters for the old and new default files:

<u>IG-91/AX: Foodstuffs; initial delays; preparation losses; bantimes</u>					
Nr. 1 - 5:	MILK	COWSMEAT	COWLIVER	PORK	SHPMEAT
Initial delay:	0.	0.	0.	- see -	0.
f preparation:	1.	1.	1.	- text-	1. ¹⁾
Nr. 6 - 10:	SHPLIVER	GREENVEG	ROOTVEG	POTATOES ²⁾	GRAINPRD ²⁾
Initial delay:	0.	0.	0.	0.	0.
f preparation:	1.	0.2	1.	1.	0.1 ¹⁾
<u>Banarray</u>					
Nr. 1 - 5:	0 A	7 D	30 D	90 D	180 D
Nr. 6 - 10:	1 A	2 A	5 A	10 A	20 A
Nr. 11 - 12:	50 A	100 A			
<u>IG-90/BX: Foodstuffs; initial delays; preparation losses; bantimes</u>					
Nr. 1 - 5:	MILK	BEEF	PORK	GRAINPRD ²⁾	POTATOES ²⁾
Initial delay:	1 d	8 d	1 d	45 d	7 d
f preparation:	1.	1.	1.	0.75	0.9 ¹⁾
Nr. 6 - 8:	LF.VGTBL	NL.VGTBL	ROOTVGTB		
Initial delay:	1 d	7 d	7 d		
f preparation:	0.75	0.9	0.9		¹⁾
<u>Banarray</u>					
Nr. 1 - 5:	0 A	1 A	2 A	5 A	10 A
Nr. 6 - 10:	20 A	50 A	100 A		
¹⁾ f preparation: fraction of the external component of the contamination remaining after the preparation of the foodstuffs for consumption.					
²⁾ In the models, it is assumed that these foodstuffs are cropped periodically and are consumed over a period of one year after each harvest; the initial delay is here the span between the cropping time and the begin of the one year consumption period.					

Table 3. IG-91/AX, IG-90/BX: Parameters relevant for the specification of NAMELIST variables

The **initial delay** is the time span between the production (i.e. slaughter, cropping) of the foodstuffs and the time the consumption is assumed to begin. From the table it can be seen, that the ECOSYS data already contain such delay times, whereas the FARMLAND data do not. For the latter, the initial delays are accounted for with the NAMELIST variables FDELAY, PDELAY, and FBDLAY; the actual values for these variables are given in the USER GUIDE (Chapter "Input group INGESTI" in Part II and Part IV).

2.4 TIME-INTEGRATED NORMALIZED ACTIVITY LEVELS AND EFFECTIVE DOSES

Table 4 on page 2-6 to Table 8 on page 2-9 give time-integrated information about the normalized activity levels in food and the resulting effective dose equivalents. The nuclides considered are I-131, Cs-134 and Cs-137, which are the most relevant ingestion nuclides for releases from LWRs. All values are normalized to unit initial deposit of the corresponding nuclide. For IG-91/AX, no additional initial delays were taken into account.

Table 4 shows the normalized time-integrated activity in the various foodstuffs for releases on July 1st and January 1st, respectively. The integration time intervals are 0 - 100 years after the assumed release.

The differences between the values from the two models range from moderate to large and vary both with the radionuclides and foodstuffs. However, some systematic effects can be observed:

- I-131, release on July 1st: IG-90/BX gives somewhat higher concentrations in milk and leafy vegetables than IG-91/AX does; for the other foodstuffs, the concentrations are lower. Introduction of a factor for the initial delays not directly accounted for in the IG-91/AX data will increase the first differences and diminish the latter.
- I-131, release on January 1st: IG-90/BX gives negligible contributions from all foodstuffs. In IG-91/AX, there is a significant contribution from I-131 by green vegetables, which is due to the continuous production model.

Table 5 gives the normalized committed effective dose equivalents estimated for the ingestion of all foodstuffs under the assumption of local production and consumption of the foodstuffs. The values were derived for adults with the consumption rates and dose-per-unit-intake factors listed in Table 6. It can be seen that for a release in July the doses calculated with IG-91/AX are systematically about one half of the doses obtained with IG-90/BX; the differences between the doses for a release in January vary unsystematically with the nuclides. It is noteworthy that in IG-91/AX the values for Cs-134 and Cs-137 are relatively similar for both release times, whereas in IG-90/BX this is observed only for a release in July. Here, in January the Cs-137 value is predicted to be about one order of magnitude higher than that of Cs-134.

Table 7 and Table 8 show the relative contributions of the foodstuffs to the normalized committed effective dose equivalents for releases on July 1st and January 1st, respectively. Especially for the January release, the differences between the two data sets are large, both quantitatively and qualitatively.

nuclide	foodstuff	release July 1st		release January 1st	
		IG-91/AX	IG-90/BX	IG-91/AX	IG-90/BX
I -131	MILK	1.93E-03	5.71E-03	1.49E-09	6.91E-11
CS-134	MILK	1.18E-02	4.30E-02	7.39E-04	4.14E-04
CS-137	MILK	1.35E-02	5.07E-02	9.36E-04	4.95E-03
I -131	COWSMEAT	8.18E-04	3.72E-05	6.35E-10	4.50E-13
CS-134	COWSMEAT	5.92E-02	4.49E-02	3.26E-03	3.86E-04
CS-137	COWSMEAT	6.97E-02	5.63E-02	4.17E-03	4.96E-03
I -131	COWLIVER	8.18E-04	not modelled	6.35E-10	not modelled
CS-134	COWLIVER	5.92E-02	in	3.26E-03	in
CS-137	COWLIVER	6.97E-02	IG-90/BX	4.17E-03	IG-90/BX
I -131	SHPMEAT	1.04E-03	not modelled	1.40E-09	not modelled
CS-134	SHPMEAT	1.59E-01	in	1.51E-02	in
CS-137	SHPMEAT	1.96E-01	IG-90/BX	4.00E-02	IG-90/BX
I -131	SHPLIVER	1.04E-03	not modelled	1.40E-09	not modelled
CS-134	SHPLIVER	1.59E-01	in	1.51E-02	in
CS-137	SHPLIVER	1.96E-01	IG-90/BX	4.00E-02	IG-90/BX
I -131	PORK	taken over	9.13E-07	taken over	0.00E+00
CS-134	PORK	from	1.97E-01	from	3.26E-04
CS-137	PORK	IG-90/BX	2.54E-01	IG-90/BX	5.19E-03
I -131	GREENVEG	1.25E-03	not modelled	1.66E-03	not modelled
CS-134	GREENVEG	3.73E-03	in	9.08E-03	in
CS-137	GREENVEG	4.25E-03	IG-90/BX	9.85E-03	IG-90/BX
I -131	LF.VGTBL	not modelled	5.42E-03	not modelled	2.93E-11
CS-134	LF.VGTBL	in	1.24E-02	in	1.22E-04
CS-137	LF.VGTBL	IG-91/AX	1.41E-02	IG-91/AX	1.70E-03
I -131	NL.VGTBL	not modelled	5.70E-06	not modelled	4.96E-14
CS-134	NL.VGTBL	in	2.50E-03	in	1.36E-04
CS-137	NL.VGTBL	IG-91/AX	4.74E-03	IG-91/AX	2.03E-03
I -131	ROOTVEG	3.15E-04	1.46E-04	1.65E-14	4.96E-14
CS-134	ROOTVEG	5.66E-02	6.27E-02	1.36E-04	1.36E-04
CS-137	ROOTVEG	6.76E-02	7.36E-02	3.91E-04	2.03E-03
I -131	POTATOES	4.02E-05	2.74E-06	1.59E-14	1.03E-15
CS-134	POTATOES	9.95E-03	7.72E-02	3.82E-05	1.31E-04
CS-137	POTATOES	1.23E-02	9.83E-02	4.89E-04	2.04E-03
I -131	GRAINPRD	2.57E-05	1.63E-06	4.38E-15	0.00E+00
CS-134	GRAINPRD	3.49E-02	9.10E-02	5.87E-05	1.08E-04
CS-137	GRAINPRD	4.24E-02	1.16E-01	7.04E-04	1.70E-03

Physical unit: $[(a \cdot \text{Bq/kg}) / (\text{Bq/m}^2)]$
Integration time: 0-100 a after assumed release

Table 4. IG-91/AX, IG-90/BX: Time-integrated normalized activity in food

		release: 1. July			release: 1. January		
		IG-91/AX	IG-90/BX	ratio	IG-91/AX	IG-90/BX	ratio
		-----	-----	-----	-----	-----	-----
Food sum	I -131	4.08E-09	1.01E-08	0.40	9.82E-10	1.12E-16	8E+6
Food sum	CS-134	3.45E-07	6.00E-07	0.58	1.20E-08	1.94E-09	6.19
Food sum	CS-137	2.98E-07	5.24E-07	0.57	1.44E-08	1.83E-08	0.79

All values for adults.
Physical unit: [Sv/(Bq/m²)].
Food intake time: 0 - 100 a after assumed release.
Dose integration time: 50 a.

Table 5. IG-91/AX, IG-90/BX: Normalized effective dose equivalent

foodstuff	consumption rates (kg/a)		dose-per-unit-intake (Sv/Bq)	
	IG-91/AX	IG-91/AX	nuclide	
-----	-----	-----	-----	
MILK	115.	115.	I -131	1.32 E-08
COWSMEAT	23.	25.		
COWLIVER	2.	--	Cs-134	1.92 E-08
PORK	50.	50.		
SHPMEAT	1.3	--	Cs-137	1.33 E-08
SHPLIVER	0.2	--		
GREENVEG	45.	--		
LF.VGTBL	--	20.		
NL.VGTBL	--	25.		
ROOTVGTB	15.	15.		
POTATOES	70.	70.		
GRAINPRD	95.	95.		

Table 6. Assumed consumption rates and dose-per-unit intake factors

IG-91/AX: Value = sum over all foodstuffs [Sv/(Bq/m**2)] (all values for adults) July 1st

value	nuclide	contributions of foodstuffs					
4.08E-09	I -131	MILK(71.5%)	GREENVEG(18.1%)	COWSMEAT(6.1%)	ROOTVEG(1.5%)	POTATOES(0.9%)	
		GRAINPRD(0.8%)	COWLIVER(0.5%)	SHPM EAT(0.4%)	SHPLIVER(0.1%)	PORK(0.0%)	
3.45E-07	CS-134	PORK(54.8%)	GRAINPRD(18.5%)	COWSMEAT(7.6%)	MILK(7.6%)	ROOTVEG(4.7%)	
		POTATOES(3.9%)	SHPM EAT(1.2%)	GREENVEG(0.9%)	COWLIVER(0.7%)	SHPLIVER(0.2%)	
2.98E-07	CS-137	PORK(56.8%)	GRAINPRD(18.0%)	COWSMEAT(7.2%)	MILK(6.9%)	ROOTVEG(4.5%)	
		POTATOES(3.8%)	SHPM EAT(1.1%)	GREENVEG(0.9%)	COWLIVER(0.6%)	SHPLIVER(0.2%)	

IG-90/BX: Value = sum over all foodstuffs [Sv/(Bq/m**2)] (all values for adults) July 1st

value	nuclide	contributions of foodstuffs					
1.01E-08	I -131	MILK(85.4%)	LF.VGTBL(14.1%)	ROOTVGTB(0.3%)	BEEF(0.1%)	POTATOES(0.0%)	
		GRAINPRD(0.0%)	NL.VGTBL(0.0%)	PORK(0.0%)			
6.00E-07	CS-134	PORK(31.5%)	GRAINPRD(27.7%)	POTATOES(17.3%)	MILK(15.9%)	BEEF(3.6%)	
		ROOTVGTB(3.0%)	LF.VGTBL(0.8%)	NL.VGTBL(0.2%)			
5.24E-07	CS-137	PORK(32.3%)	GRAINPRD(28.0%)	POTATOES(17.5%)	MILK(14.8%)	BEEF(3.6%)	
		ROOTVGTB(2.8%)	LF.VGTBL(0.7%)	NL.VGTBL(0.3%)			

Note:

Food intake time: 0-100 a after assumed release / Dose integration time: 50a

Table 7. IG-91/AX, IG-90/BX: Foodstuff contributions to normalized effective dose equivalent (July 1st)

IG-91/AX: Value = sum over all foodstuffs [Sv/(Bq/m**2)] (all values for adults) January 1st

value	nuclide	contributions of foodstuffs									
9.82E-10	I -131	GREENVEG(100.0%)	MILK(0.0%)	COWSMEAT(0.0%)	SHPMEAT(0.0%)	COWLIVER(0.0%)	SHPLIVER(0.0%)	POTATOES(0.0%)	GRAINPRD(0.0%)	ROOTVEG(0.0%)	PORK(0.0%)
1.20E-08	CS-134	GREENVEG(65.4%)	MILK(13.6%)	COWSMEAT(12.0%)	SHPMEAT(3.1%)	PORK(2.6%)	COWLIVER(1.0%)	GRAINPRD(0.9%)	SHPLIVER(0.5%)	POTATOES(0.4%)	ROOTVEG(0.3%)
1.44E-08	CS-137	GREENVEG(41.0%)	PORK(24.0%)	MILK(10.0%)	COWSMEAT(8.9%)	GRAINPRD(6.2%)	SHPLIVER(4.8%)	POTATOES(3.2%)	COWLIVER(0.8%)	SHPLIVER(0.7%)	ROOTVEG(0.5%)

IG-90/BX: Value = sum over all foodstuffs [Sv/(Bq/m**2)] (all values for adults) January 1st

value	nuclide	contributions of foodstuffs							
1.12E-16	I -131	MILK(93.0%)	LF.VGTBL(6.9%)	BEEF(0.1%)	NL.VGTBL(0.0%)	ROOTVGTB(0.0%)	POTATOES(0.0%)	GRAINPRD(0.0%)	PORK(0.0%)
1.94E-09	CS-134	MILK(47.2%)	PORK(16.2%)	GRAINPRD(10.2%)	BEEF(9.6%)	POTATOES(9.1%)	NL.VGTBL(3.4%)	LF.VGTBL(2.4%)	ROOTVGTB(2.0%)
1.83E-08	CS-137	MILK(41.5%)	PORK(18.9%)	GRAINPRD(11.8%)	POTATOES(10.4%)	BEEF(9.0%)	NL.VGTBL(3.7%)	LF.VGTBL(2.5%)	ROOTVGTB(2.2%)

Note:
Food intake time: 0-100 a after assumed release / Dose integration time: 50a

Table 8. IG-91/AX, IG-90/BX: Foodstuff contributions to normalized effective dose equivalent (January 1st)

2.5 REFERENCES

- [1] BSF, GSF, IPSN, RIVM and NRPB. Post-Chernobyl Action 5, Underlying Data for Derived Intervention Levels - Chapter 2: Foodchain models and modelling. Luxembourg, CEC EUR 12533 (1991).
- [2] J.R. SIMMONDS, G.S. LINSLEY, J.A. JONES. A General model for the transfer of radioactive materials in terrestrial foodchains. Chilton, NRPB-R89 (1979).
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- [4] J. R. SIMMONDS. The Influence of Season of the Year on the Transfer of Radionuclides to Terrestrial Foods following an Accidental Release to Atmosphere. Chilton, NRPB-M121 (1985).
- [5] G. PRÖHL. Modellierung der Radionuklidausbreitung in Nahrungsketten nach Deposition von Sr-90, Cs-137 und I-131 auf landwirtschaftlich genutzten Flächen. Neuherberg, GSF-Bericht 29/90 (1990).
- [6] COSYMA: User guide (Version 90/1). Compiled by I. Hasemann and J.A. Jones. Brussels and Karlsruhe, Report EUR 13045/KfK-4331B (1991).
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- [10] BSF, GSF, IPSN, RIVM and NRPB. Post-Chernobyl Action 5, Underlying Data for Derived Intervention Levels - Chapter 3: Food consumption. Luxembourg, CEC EUR 12533 (1991).
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3. THE NRPDCF91 DOSE CONVERSION FACTORS FOR INGESTION

3.1 DESCRIPTION OF THE DATA

The dose-per-unit-intake data designated NRPDCF91 are based on a file provided by the National Radiological Protection Board (NRPB, UK), which gives for an individual with a given age at the time of ingestion the cumulative dose equivalent resulting from a single intake of activity as a function of the time after the intake [1]. The buildup of activity from radioactive decay chains after ingestion is included in the dose factors. The data are given for 24 organs, six age groups, several gut transfer factors f1, and seven integration times. Except for the organs breast, uterus, ovaries and testes, the values represent averages over both sexes.

The original file needs some modifications before it can be applied in COSYMA. The reasons lay partly in differences between the file structures, and partly in the fact that some data are not needed, while others are missing. Apart from the reorganization of the file structure, the following changes are necessary:

- Reduction to only one f1-value for adults and infants, respectively. For all other age groups, the corresponding f1-value of adults is used. The choice of the appropriate values follows the recommendations given in [1]; the resulting values are shown in Table 9:

element	adults	infants ¹⁾	element	adults	infants ¹⁾
-----	-----	-----	-----	-----	-----
V	1.0E-02	2.0E-02	Cr	1.0E-01	2.0E-01
Mn	1.0E-01	2.0E-01	Fe	3.0E-01	6.0E-01
Co	3.0E-01	6.0E-01	Ni	5.0E-02	1.0E-01
Sr	3.0E-01	6.0E-01	Y	1.0E-03	1.0E-02
Zr	1.0E-02	2.0E-02	Nb	1.0E-02	2.0E-02
Mo	8.0E-01	1.0E+00	Ru	5.0E-02	1.0E-01
Te	2.0E-01	4.0E-01	I	1.0E+00	1.0E+00
Cs	1.0E+00	1.0E+00	Ba	1.0E-01	2.0E-01
Ce	3.0E-04	3.0E-03	W	3.0E-01	6.0E-01
Np	5.0E-04	5.0E-03	Pu	5.0E-04	5.0E-03
Am	5.0E-04	5.0E-03	Cm	5.0E-04	5.0E-03

¹⁾ infants aged 3 months (before weaning)

Table 9. NRPDCF91: Gut transfer factors

- Removal of data for organs not used in COSYMA.
- The original file does not include data for colon, gonads, and the type of remainder required for the risk calculations with COSYMA. The missing information is obtained in the following way:
 - **Colon:** Maximum of lower large intestine (L.L.I.) and upper large intestine (U.L.I.).

- **Gonads:** Arithmetic mean of ovaries and testes.
- **Remainder:** Arithmetic mean over the 5 most significant doses from the organs adrenals, bladder, brain, kidneys, skin, spleen, small intestine (S.I.), thymus, uterus.
- The original file contains effective dose factors according the ICRP-60 recommendations [2], but not those according to ICRP-26 [3]. For ingestion, the latter ones are derived from the available data with the weights listed in Table 10. The 10% - cut introduced by ICRP-30 [4] was not applied.

----- weighted organs -----		----- organs used for rest-of-body ¹⁾ -----			
breast	0.15	adrenals	bladder	brain	kidneys
bone surface	0.03	liver	L.L.I.	pancreas	S.I.
red bone marrow	0.12	skin	spleen	stomach	thymus
lungs	0.12	U.L.I.	uterus		
thyroid	0.03				
gonads ²⁾	0.25				

Notes:

¹⁾ rest-of-body = the five most significant organs from above list weighted each with 0.06 (total weight for rest-of-body = 0.30).

²⁾ gonads = arithmetic mean of ovaries and testes

Table 10. NRPDCF91: Calculation of the ICRP-26 effective dose equivalent for ingestion

Some preprocessors do not use the cumulative dose-per-unit-intake data, but require yearly values with respect both to the age at ingestion and to the time after the (single) intake. These data are derived for each organ and radionuclide from the cumulative values in the following way:

- *Step 1:* The cumulative data are differentiated with respect to the time after the intake and parameterized in time steps with a spacing of one year each. For all time intervals defined by the integration times of the original data, the differential values are obtained under the assumption of a linear relationship between the corresponding lower and upper interval boundaries.
- *Step 2:* The one value for each age group is assigned to all ages between the corresponding lower and upper age boundaries to generate the data in age steps with a spacing of one year of age each.

For more details see [5] Part IV.C or the source code of the preprocessor which produces the differential data.

3.2 REFERENCES

- [1] A.W. PHIPPS, G.M. KENDALL, J.W. STATHER, T.P. FELL. Committed Equivalent Organ Doses from Intakes of Radionuclides. Chilton, NRPB-R245 (1991) (London, HMSO).
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4. THE GSFRCF88 RISK CONVERSION FACTORS

4.1 DESCRIPTION OF THE DATA

The risk conversion factors for fatal stochastic somatic health effects incorporated in the default activity-risk coefficients of COSYMA were made available by the GSF - Forschungszentrum für Umwelt und Gesundheit (FRG) [1]. The original data were averaged with respect to sex¹⁾ and restructured to comply with the file requirements of COSYMA.

Average risk conversion factors are shown in Table 11, where they are expressed in terms of the number of fatal cancers per million people for a single exposure of 0.01 Sv, assuming the age structure and natural cancer incidence of the FRG population. These average values are used in COSYMA for the assessments of collective health effects from ingestion with the agricultural production approach.

<u>organ/tissue</u>	<u>effect</u>	<u>model¹⁾</u>	<u>risk²⁾</u>
breast	cancers	R	80 ³⁾
bone surface	cancers	A	1
lung	cancers	R	90
red bone marrow	leukemia	A	52
thyroid	cancers	R	17
remainder	cancers	R	38
stomach	cancers	R	91
colon	cancers	R	34
liver	cancers	R	47
pancreas	cancers	R	53

Notes:
¹⁾ A: absolute risk model; R: relative risk model.
²⁾ Linear dose-response-relationship assumed.
³⁾ Average value for the population.

Table 11. GSFRCF88: Average risk factors for fatal cancers

4.2 REFERENCES

- [1] K. HENRICH, H.G. PARETZKE, D. CHMELEVSKY, M. GERKEN. New estimates of risk surfaces for late somatic effects of low doses of ionizing radiation. In: Proceedings of the joint OECD (NEA)/CEC Workshop on "Recent Advances in Reactor Accident Consequence Assessment", Rome, Italy, January 25-29 (1988). Commission of the European Communities, EUR - 11408 EN, p. 271 - 277 (1988).

¹⁾ Exception: Breast. In COSYMA, the values for breast must refer to females only.

5. THE 91/1 CONSUMPTION RATES

5.1 DESCRIPTION OF THE DATA

The default COSYMA consumption rates 91/1 were obtained from statistical information about food consumption in the FRG; they refer to "foodstuffs ready for consumption" for average consumers in six age groups. The underlying data stem mainly from household budget surveys between 1965 - 1981. Details about the origin of the source data and the derivation of the COSYMA rates are given in [1], and the age-dependent consumption rates assumed in the calculation of the activity-risk coefficients can be found in the chapter "Input group INGESTI" in Part III and Part IV of the COSYMA USER GUIDE [2].

Table 12 on page 5-2 lists the COSYMA consumption rates for adults and mean rates obtained from the age-dependent data assuming the age structure of the FRG. These rates are compared with the consumption rates for an "average European citizen" from reference [3]. This reference also gives values for individual countries, the minimum and maximum of which are shown to indicate the spread in the EC countries.

The consumption rates for the "average European citizen" are averaged over all ages. According to [3], they are expressed as the amount of "raw, unprepared products available for consumption":

- **Milk:** It is distinguished between "fresh dairy products" (drinking milk and fresh milk products) and "other dairy products" (butter, cheese, milk powder and condensed milk). For both types, the consumption rates refer to the amount consumed, and not to the amount of milk used to produce the products.
- **Meat:** The data for meat are expressed as "carcass weight", in which fat and bone is included. Reference [3] gives contributions of 20% and 5% to the carcass weight for bone and fat, respectively, and an average shrinkage in frying for meat as 30% of the raw weight.
- **Vegetables and potatoes:** Reference [3] gives an average remaining part of raw weight after cleaning of 80% for all vegetables combined and for potatoes, and an overall factor of 13% for shrinkage in cooking for vegetables.
- **Grain products:** No conversion factor specified.

The factors for waste are included in Table 12 (f edible), but not those for shrinkage in cooking or frying.

It can be seen from the table, that, with the given age-structure of the population, the COSYMA consumption rates for adults do not differ by more than 15% from the corresponding age-averaged consumption rates for all foodstuffs considered.

A comparison of the COSYMA and the EC consumption rates shows a good agreement for the total milk consumption and the consumption of potatoes and grain products.

Taking into account the factor to convert carcass weight to edible meat, the consumption of beef and, especially, pork, in COSYMA significantly exceeds the European average, whereas the consumption of lamb is rather low in comparison.

For vegetables, the COSYMA consumption rates are lower than the European average by factors of 0.5 - 0.7, which reflects the fact that the FRG consumption of vegetables is in the lower range of the EC values, as can be seen from Tab. 3.5 of reference [3] .

foodstuff	COSYMA		"average European citizen"		
	adults (kg/a)	mean (kg/a)	mean (kg/a)	(min / max) (kg/a)	f edible
-----	-----	-----	-----	-----	-----
milk (fresh + products) * fresh milk ²⁾	115 82% ³⁾	111	124 82%	(49 / 206) (74% / 95%)	1.0 ¹⁾
meat (sum of m1-m3)	77	68	64		0.75
(m1) beef & veal	25	21	23	(11 / 32)	
(m2) pork	50	46	37	(19 / 64)	
(m3) lamb, mutton, goat	1.5	1.4	4 ⁴⁾	(0.5 / 12) ⁴⁾	
vegetables (sum of v1-v3)	60	58	122 ⁵⁾		0.8
(v1) leafy vegetables	20	19	38	(25 / 56)	
(v2) fruit vegetables	25	25	60	(12 / 109)	
(v3) root vegetables	15	14	24	(13 / 37)	
potatoes	70	59	81	(35 / 126)	0.8
grain products	95	85	84	(58 / 115)	1.0 ¹⁾
* wheat	--	--	87%		

Notes:

1) Fraction not specified in [3]; 1.0 is assumed.

2) Fresh milk = drinking milk and fresh milk products.

3) 82% if condensed milk and cream are included; 72% if they are not.

4) Average EC values are not given in [3]. The mean value in this table is the arithmetic mean of the values for individual countries from from Tab. 3.5 of [3]; the minimum and maximum values are taken from the same table.

5) Average EC values for the three types of vegetables are not given in [3], only a vegetable sum of 110 kg/a. The values in above table are the arithmetic mean of the values for individual countries from Tab. 3.5 of [3].

Table 12. A comparison of the 91/1 consumption rates with average EC rates

5.2 REFERENCES

- [1] C. STEINHAEUER. UFOING: A program for assessing the off-site consequences from ingestion of accidentally released radionuclides. Karlsruhe, KfK-4475 (1988).
- [2] COSYMA: User guide. Compiled by I. Hasemann and J.A. Jones. Brussels and Karlsruhe, Report EUR 13045/KfK-4331B (1991).
- [3] BSF, GSF, IPSN, RIVM and NRPB. Post-Chernobyl Action 5, Underlying Data for Derived Intervention Levels - Chapter 3: Food consumption. Luxembourg, CEC EUR 12533 (1991).

6. THE 91/1 AGRICULTURAL PRODUCTION DATA

The COSYMA program package includes a library giving the amount of agricultural produce on a latitude-longitude grid. The conversion to the input format required by COSYMA is done with the program GRIDS (see Part VI of the COSYMA USER GUIDE [1]).

6.1 AGRICULTURAL PRODUCTION USED FOR HUMAN CONSUMPTION

The 91/1 agricultural production for human consumption data were provided by the National Radiological Protection Board (NRPB, UK) on a 100 km × 100 km grid covering the EC and large parts of the Eastern Countries. The source of the data for each country is described in [2].

With the exception of milk products, all data refer to "foodstuffs ready for human consumption". The following food items are included:

- Milk: To items for milk are given: "fresh milk" and "milk products". According to [2] (Chapter 2.2.2), this division is based on the following delays between harvest and consumption:
 - Short delay (≤ 1 month) \leftrightarrow "Fresh milk", which includes liquid fresh milk, sour cream and fresh cheese.
 - Longer delay (> 1 month) \leftrightarrow "Milk products", which includes cheese, powdered milk and evaporated milk.

Milk converted to cream and butter was not included in the grid since the transfer of radionuclides to fatty material was assumed to be small. Milk products are recorded in the grid in terms of litres of milk equivalent.

- Cow's meat.
- Cow's liver.
- Sheep meat.
- Sheep liver.
- Grain products: wheat, barley and oats.
- Green vegetables: cabbage, cauliflower, Brussels sprouts, lettuce, peas, runner and French beans.
- Root crops: potatoes, carrots, turnips, swedes, parsnips, onions, beetroot.

Table 13 shows the average annual per caput production derived from the default grid data, i.e. the ratio of the total amount of annual production in the grid and the total number of individuals in the corresponding area taken from the COSYMA default population grid data:

fresh milk	milk prod.	cow's meat liver	sheep meat liver	green veg.	root- crops	grain prod.		
(1/a)	(1/a)	(kg/a)	(kg/a)	(kg/a)	(kg/a)	(kg/a)		
117	77	15	0.47	1.7	0.11	61	209	345

Table 13. Average annual per caput production derived from the default production grid data

A comparison of these values with average EC consumption rates from [3] (see also Chapter " 5. The 91/1 consumption rates") shows, that for almost all foodstuffs the average annual per caput production derived from the grid data is within the minimum - maximum range of the average EC consumption rates. The exceptions are root crops and grain products, which significantly exceed the maximum European consumption rates. The reason for this excess is not clear; however, it seems likely that a certain amount of food consumed by animals or food exported outside the grid area is included in the grid data.

6.2 AGRI-ECONOMIC PRODUCTION

Corresponding to the agricultural production for human consumption data grid data for the agri-economic production were provided by [2]. The following items are included:

- Milk (including milk products expressed in terms of litres of milk).
- Lifestock: Beef cattle and sheep.
- Crop area: Area in each grid element used for growing the crops mentioned in the preceding chapter.

6.3 REFERENCES

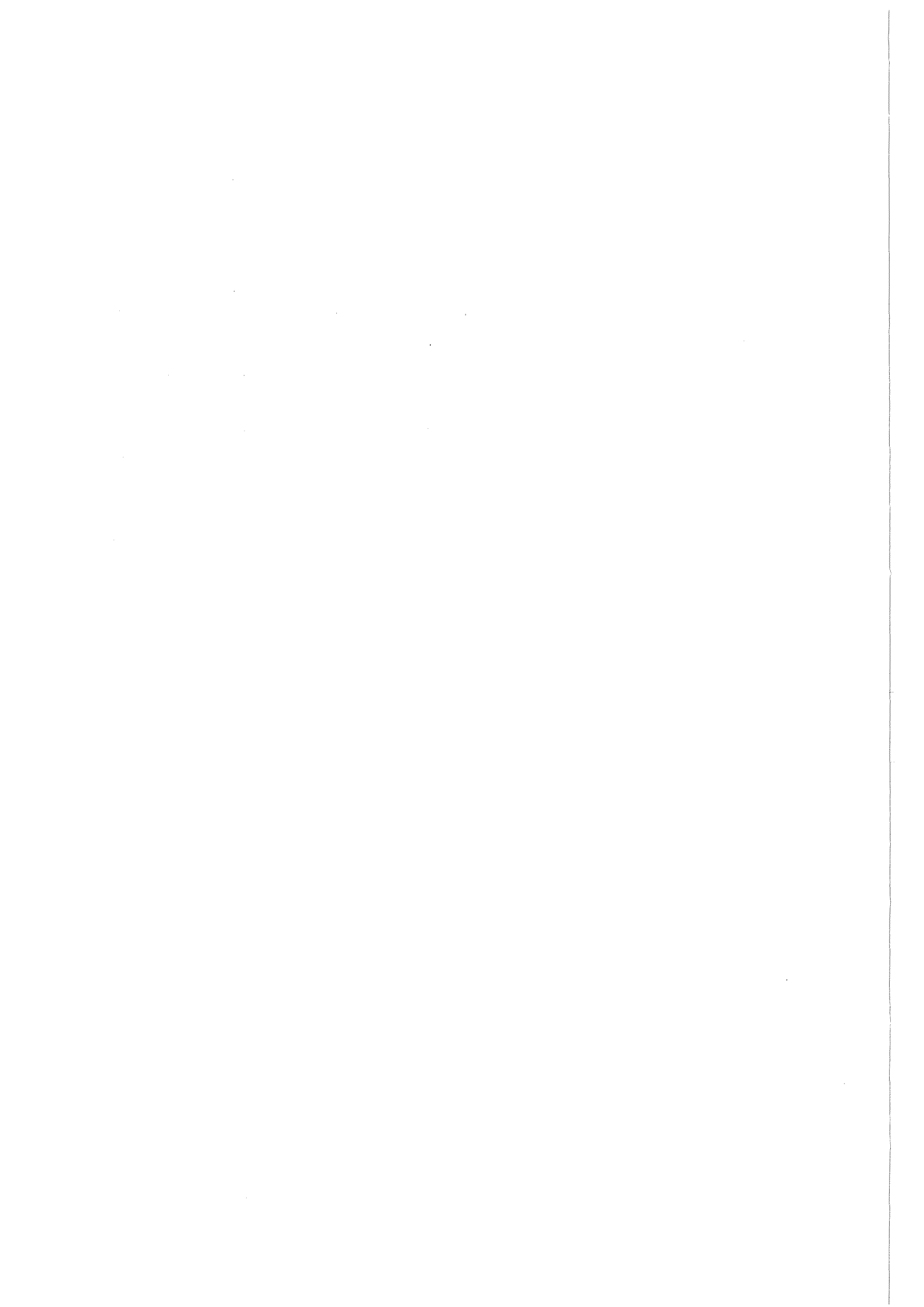
- [1] COSYMA: User guide. Compiled by I. Hasemann and J.A. Jones. Brussels and Karlsruhe, Report EUR 13045/KfK-4331B (1991).
- [2] M. BROOMFIELD, J.R. SIMMONDS, T.A. CHAPMAN. POP-MARC and AG-MARC: Population and agricultural distributions for use in the methodology for assessing the radiological consequences of accidental releases. Chilton, NRPB-M75 (1982).
- [3] BSF, GSF, IPSN, RIVM and NRPB. Post-Chernobyl Action 5, Underlying Data for Derived Intervention Levels - Chapter 3: Food consumption. Luxembourg, CEC EUR 12533 (1991).

Part IV

General information about the ingestion data files

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1. OVERVIEW OF THE INGESTION DATA FILES

Table 1 shows the ingestion data files which are used in ingestion-related accident consequence assessments (ACAs) with COSYMA or COSING or by the data file creating preprocessor programs (PREP) of COSING. The files marked by a '+' are routinely supplied with the COSYMA program package, all others can be made available on request. The files which contain either explicitly or implicitly activity levels in food vary with the time of the assumed release and are season - dependent; this is indicated by a '*' in the table.

file name	data	availability	and use
-----	----	-----	-----
DEFAULTS	Default values	+	COSYMA COSING
INGNUKLS	Ingestion nuclides	* +	COSYMA COSING PREP
	Activity levels in food		
aaabbbPR	- for accident consequence assessments	* +	COSYMA COSING
aaabbbSP	- for ADCs/ARCs etc.	*	PREP
	Dose-per-unit-intake (ingestion)		
aaaDPUI0	- base for DPUI1 and DPUI0		PREP
aaaDPUI1	- for accident consequence assessments	+	COSYMA COSING
aaaDPUI0	- for ADCs/ARCs etc.		PREP
aaaARCii	Activity-risk coefficients (ingest.)	* +	COSYMA COSING
aaaADCii	Activity-dose coefficients (ingest.)	*	COSING
aaaRCFjj	Risk conversion factors for ARCs etc.		PREP
FCRaaakk	Consumption rates for ADCs, ARCs etc.		PREP

where

- * marks files which depend on the assumed time of the release.
- + marks files routinely supplied with the COSYMA program package.
- aaa stands for some three character abbreviation of the origin of the source data (e.g. FAR for FARMLAND; NRP for NRPB etc.).
- bbb stands for some three character abbreviation of the month of the release (e.g. JAN for January; JUL for July).
- ii stands for the number of the month of the release (e.g. 07 for July)
- jj stands for the year the data were received (e.g. 91 for 1991).
- kk stands for the number of foodstuffs in the file.

Table 1. List of ingestion data files (except grid data)

All those default values for the NAMELIST variables in input group INGESTI, which are provided with the COSYMA program package, are contained in the *formatted* data file DEFAULTS. All other ingestion data files are *unformatted*; the ones provided with the COSYMA program package are created with preprocessor programs of COSING.

File INGNUKLS contains all nuclide-relevant information required by COSING, the ingestion part of COSYMA, or the COSING preprocessors. In particular, it must include the names of all those nuclides, for which data exist in any of the ingestion data files (the "ingestion nuclides").

The activity-in-food file characterized by the two characters PR is only used for ACA calculations (PR stands here for 'processing'). The additional 'special' or SP-file is required for several of the preprocessors, for example the programs which create the activity-risk coefficients (ARC) data files.

The dose-per-unit-intake file DPUI1 is also only used for ACA calculations; the two additional files DPUI0 and DPUI2 are necessary for the preprocessors which create the file DPUI1, and, for instance, the ARC-files.

Activity-dose coefficients (ADCs) are used exclusively in COSING for the estimation of age-dependent organ doses from ingestion under the assumption of local production and consumption of the foodstuffs [1].

Detailed information of age-dependent consumption rates is required e.g. by the preprocessors which calculate the ADCs and the ARCS; the latter also need age-dependent risk conversion factors.

2. GENERAL FILE STRUCTURE, FILE IDENTIFIERS AND FILE HEADERS

For almost all ingestion data files, the first record in each file is the **file identifier**. The identifier consists of 80 characters with the following meaning:

Character 01-08	file name
Character 09-16	file creation date
Character 17-24	foodchain data type code ¹⁾
Character 25-32	some abbreviation for the type of the data
Character 33-48	physical unit of the data
Character 49-56	assumed date of release ¹⁾
Character 57-64	code for activity-in-food data origin ¹⁾²⁾
Character 65-72	code for dose-per-unit-intake data origin ³⁾
Character 73-80	code for risk model and data origin ⁴⁾

Notes:

- ¹⁾ Only for files which explicitly or implicitly contain activity-in-food data (else blank).
- ²⁾ Coding: Six characters for the model followed by two digits for the year the data were provided.
- ³⁾ Only for files which explicitly or implicitly contain dose conversion factors (else blank).
Coding: Three characters for the model followed by the three characters 'DCF' for "dose conversion factors" and two digits for the year the data were provided.
- ⁴⁾ Only for files which explicitly or implicitly contain risk conversion factors (else blank).
Coding: Three characters for the model followed by the three characters 'RCF' for "risk conversion factors" and two digits for the year the data were provided.

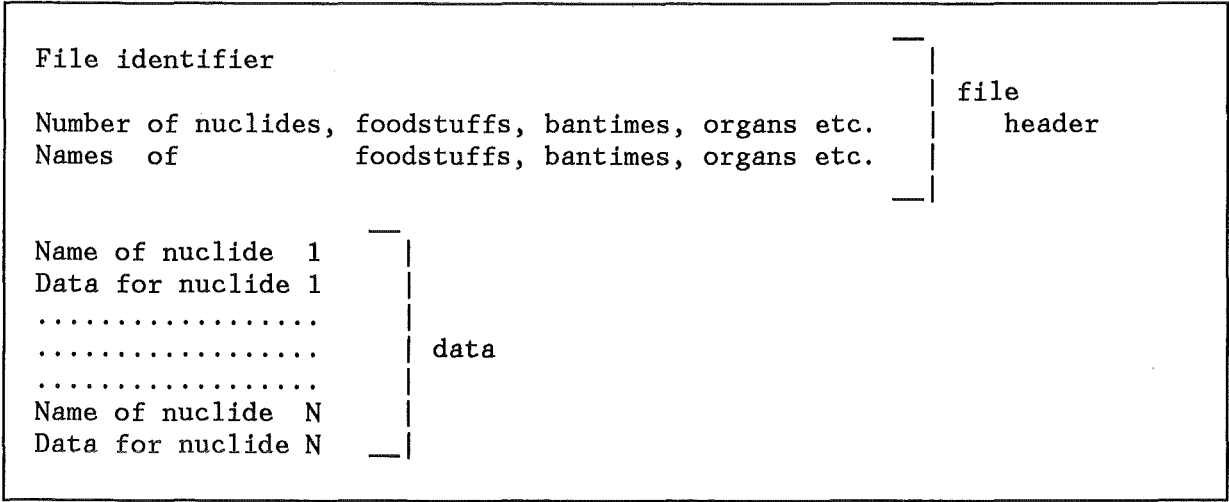
Three examples for valid file identifiers are given below:

Example 1: Activity-in-food
FARJULPR01.07.91IG-91/AX FCT-PR BQ|BQ*A//BQ/M**201. JULYFRMLND91

Example 2: Dose-per-unit-intake (ingestion)
NRPDPU1101.07.91 IG-DPUI SV/BQ INGESTED NRPDCF91

Example 3: Activity-risk coefficients (ingestion)
GSFARC0701.07.91IG-91/AX IG-ARC 1//BQ/M**2 01. JULYFRMLND91NRPDCF91GSFRCF88

The file identifier is followed by such information as, for example, how many radionuclides, foodstuffs, bantimes etc. are contained in the files and what the names of the foodstuffs, bantimes etc. are (for more details see "4. The exact structures of files and data"). The identifier together with the general information about the file contents is referred to as the **file header**. The header is followed by the data for the individual nuclides:



All ingestion-related programs recognize an ingestion nuclide by its name, provided that the name is included in the ingestion nuclides file INGNUKLS. This fact in connection with the general file structure explained above implies, that the ingestion files can contain data for any number of nuclides in any order.

3. SPECIAL RULES FOR CODING

3.1 FOODCHAIN DATA TYPE CODES AND DEFAULT SETUP CODES

For the ingestion-related calculations, information about the activity per unit mass and unit initial deposit in the consumed foodstuffs is required either explicitly or contained implicitly in some of the data, for instance in the activity-risk coefficients. The activity-in-food information is read from data files, which were generated by a foodchain transport model.

COSYMA can operate with foodchain data files of different origin. The data in the various files may differ from each other not only by the numerical value for a given foodstuff at a given time, but also by the times and foodstuffs themselves. Moreover, many of the default values COSYMA provides for the variables in input group INGESTI depend on the foodstuffs. This situation makes it necessary to prevent a mixup of default values and foodchain data at runtime, for example by using default values for Korea together with FARMLAND activity-in-food data and activity-risk coefficients derived with activity-in-food data from ECOSYS.

Therefore, all files which refer to the same activity-in-food data are characterized by a CHARACTER*8 variable called the **foodchain data type code**, which is a part of the file identifier contained as the first record in each ingestion data file:

Character 01-03	the three characters 'IG-'
Character 04-05	two digits identifying the year of installation
Character 06	the separator '/'
Character 07	one character which serves to distinguish between food-chain data types which were installed in the same year.
Character 08	the character 'X', which tells that this is a foodchain data type code (and not a default setup code; see below).

A complete set of default values for all NAMELIST variables in input group INGESTI is referred to as a **default setup**. As already mentioned, a number of these default values depend on the foodstuffs, and thus on the foodchain data type. Also, it is possible that more than one default setup exists for one given foodchain data type, for instance one for LWR runs and another one for actinide runs. To distinguish between the different default setups, each is characterized by a **default setup code**:

Characters 01-07	identical to the foodchain data type code.
Character 08	one character (except the character 'X') to distinguish between default setups to the same foodchain data type.

Example: 'IG-91/A1' and 'IG-91/A2' may designate two default setups for food-chain data of the type 'IG-91/AX'.

All default setups supplied with the COSYMA program package are contained in the DEFAULTS data file under the corresponding default setup code and described in the COSYMA USER GUIDE [2]. (chapter "Input group INGESTI" in Part III and Part IV).

The user can request a default setup by specifying the corresponding default setup code with the variable CIGSET of input group RESULTS. COSYMA then looks into the DEFAULTS file for a default setup with the name given by CIGSET. If

none is found, a warning message is issued, but execution will continue. (In this case, one must set up all the values with the NAMELIST input, else program crash). Furthermore, COSYMA always compares the name given by CIGSET with the corresponding foodchain data type code read from the data files used, and stops with an error message if the first 7 characters are not equal.¹

3.2 ORGANS IN THE INGESTION DATA FILES AND IN COSYMA/COSING

In this chapter, the word *organ* is used both for the organs in the calculations of individual and collective doses ("dose" organs) and the organs (or, rather, health effects) in the calculations of individual and collective risks ("risk" organs).

In the dose-per-unit-intake files which contain the dose conversion factors (DCF) for ingestion, up to MAXORK "dose" organs can be considered. The actual number of organs included in a file is given by the variable NORK. The number NORK and the organ names (array ORKNAM(MAXORK)) are contained in the file header.

In the ingestion activity-risk coefficients (ARC) files, up to MAXORG "risk" organs can be considered. The actual number of organs included in a file is given by the variable NORG. The number NORG and the organ names (array ORGNAM(MAXORG)) are again contained in the file header.

Any DCF-file must contain one item 'standard effective dose'. It may contain one additional item 'non-standard effective dose', which can be requested by the user with variable NEWEDE of input group RESULTS.² For example, the effective dose calculated according to the ICRP-26 recommendations [3] and the effective dose calculated according to the new ICRP-60 procedure [4] can be used as the standard and non-standard effective dose, respectively.

The following rules hold for NORG, NORK and the organs which are contained in the data files:

NORG	- must be the total number of organs COSYMA considers for the calculation of doses (!).
NORK	- must be greater or equal to NORG.
DCF-files	- the first NORG organs in the files must include all the organs COSYMA considers for the calculation of doses (but not necessarily in the order COSYMA requires; see text).

¹ As a consequence, if one does not want to use any predefined setup from the DEFAULTS file, the first 7 characters of CIGSET must be identical the first 7 characters in the foodchain data type code, and all 8 characters must not be equal to any default setup code in the DEFAULTS file. These two conditions are always fulfilled if CIGSET is set to the foodchain data type code.

² If NEWEDE is in effect, COSYMA assumes that the last item in the file is the non-standard effective dose; the user should inspect the printout of the file header to make sure that this actually is so.

(continuation from previous page)

RCF-files - the first NORG organs in the files must match the first NORG organs in the DCF-files. Exception: There is no equivalent for the effective dose in RCF files; the corresponding data can be all zero or anything else (e.g. the information TOTAL = ARC sums over all organs).

Nonstandard effective dose - if any, it must be the last item in the DCF data files, i.e. at position NORK.

The sequence of the organs in the dose conversion data files or the activity-risk coefficients files is arbitrary in the sense that it does not need to match the fixed sequence of organs or health effects in COSYMA. The mapping of the first NORG organs in the ingestion data files onto the fixed sequence used in COSYMA is done by two arrays, IGORGS ("dose" organs) and IGHEFF ("risk" organs), and one variable, ICOEDE, which tells what the address of the standard effective dose in dose data files is. These arrays/variables are initialized with DATA statements, and the following order of organs is assumed:

Number in default input data files (COSING order)	Number in COSYMA (dose calculations)	Number in COSYMA (risk calculations)
01 = 'RBMARROW' (DCF,RCF)	01	01
02 = 'BONESURF' (DCF,RCF)	02	02
03 = ' BREAST' (DCF,RCF)	03	03
04 = ' LUNG' (DCF,RCF)	04	04
05 = ' THYROID' (DCF,RCF)	09	09
06 = ' STOMACH' (DCF,RCF)	05	05
07 = ' COLON' (DCF,RCF)	06	06
08 = ' LIVER' (DCF,RCF)	07	07
09 = 'PANCREAS' (DCF,RCF)	08	08
10 = ' GONADS' (DCF,RCF)	10	11
11 = 'REMAINDR' (DCF,RCF)	11	10
12 = 'EFFCTIVE' (DCF)	12 (default)	
12 = ' TOTAL' (RCF)		(used in COSING)
13 = 'ADRENALS' (DCF)	--	--
14 = ' BLADDER' (DCF)	--	--
15 = ' BRAIN' (DCF)	--	--
16 = ' KIDNEYS' (DCF)	--	--
17 = ' SKIN' (DCF)	--	--
18 = ' SPLEEN' (DCF)	--	--
19 = ' S.I.' (DCF)	--	--
20 = ' THYMUS' (DCF)	--	--
21 = ' UTERUS' (DCF)	--	--
22 = 'EDICRP60' (DCF)	12 (on user request)	--

Table 2. Organs in the default ingestion data files and in COSYMA/COSING

The organ order shown in Table 2 is always followed in the default data files provided with the COSYMA program package. When implementing data files with a different order of organs (not recommended), IGORGS/ICOEDE and IGHEFF must be modified in all programs which make use of these variables, for example in the ingestion part of COSYMA and in the COSYMA preprocessor SOURCE. In addition, the array IFBORG for the CFBANS='DOSE' option in the DEFAULTS data file is, by technical reasons, set up for the COSING default organ order and must thus be modified accordingly. (The NAMELIST input array IFBORG in input group INGESTI is oriented on the COSYMA dose organ order, and needs no adjustment). The non-standard data files and the modified program versions can no longer be used in connection with the standard program versions and data files.

For some of the "dose"- and "risk" organs, there exist rules for the spelling and the numerical values, which must be obeyed when designing a corresponding data file:

Spelling -----	
Breast	- must be spelled ' BREAST'.
Effective dose ("dose" organ only):	
	- standard: must be spelled 'EFFCTIVE'.
	- non-standard: no spelling restrictions.
Remainder	- must be spelled 'REMAINDR'.
Numerical values -----	
Breast	- The dose/risk factors must apply to females.
All other organs:	The dose/risk factors must apply to an average member of the general population.

The spelling of all other organs is in principle arbitrary. However, some control printout is name-oriented, and it is recommended to keep to the spelling given in Table 2 on page 3-3.

3.3 CHARACTER DATA

All character items should be initialized right justified (examples: ' PORK' or ' 200 A'). With the exception of the ingestion nuclides names in file INGNUKLS (see Table 3 on page 4-3), this is merely for a nice printout and not necessary for the identification of the items by the ingestion-related programs, because the latter ignore blanks in all character data.

Only upper case characters must be used for character data.

4. THE EXACT STRUCTURES OF FILES AND DATA

4.1 THE FORMATTED FILE DEFAULTS

The file DEFAULTS contains the default values for COSYMA/COSING; it is the only ingestion data file which is formatted and created by hand and not by an auxiliary program.

Modifications of the file supplied with the COSYMA program package in the sense that the existing default values are altered is not allowed. However, the user may add a setup of his own design with an appropriate default setup code to the file. In this case, the following procedure is recommended:

1. Read chapters "Foodchain data type codes and default setup codes" and "Character data".
2. Have a close look at the DEFAULTS file and at the FORTRAN subroutine RDDFLT of COSYMA.
3. In file DEFAULTS:
 - a. The first line contains the number of default setups included in the file (+ MDEF directive). Increase this number by one.
 - b. Add the name of the new setup code to the table of contents (the position is arbitrary). Specify the total number of lines the new setup will require with the + MSKIP directive.
 - c. Add the new setup to the file. The position must correspond to the position of the setup code name in the table of contents. For example, if the old table of contents originally contained five entries, and the new setup code was placed between the old entries two and three, the new block of default values must come as the third block in the file.
4. Set NAMELIST variable CIGSET in input group RESULTS to the name of the new setup code and test it carefully by exercising COSYMA with it.

4.2 THE UNFORMATTED FILES

Details about the file structures and the data in the unformatted files are given from Table 3 on page 4-3 to Table 9 on page 4-9. In these tables, the meaning of variables is only explained if this is necessary for the understanding of the parameterization of the data. In all other cases, the reader is referred to chapter " 5. Frequently used variables and arrays".

In all files which refer to bantimes and foodstuffs, up to MAXBAN foodban times and MAXFOO foodstuffs can be considered. The NBAN times actually contained in a file make up the *banarray*; they are defined with a REAL array BANTIM(MAXBAN) and a CHARACTER*8 array BANNAM(MAXBAN). The number of foodstuffs in a file is given by variable NFOO, and the names of the foodstuffs by a CHARACTER*8 array FOONAM(MAXFOO). NBAN, BANTIM, BANNAM, NFOO and FOONAM are always included in the file header.

The times for the foodbans and the foodstuffs possible with a given foodchain data type, which are contained in the headers of the activity levels in food files, are used as references: whenever foodban times or foodstuffs are encountered in the file headers of other files, they are compared with those from the activity-in-food data file, and execution is terminated with an error message from COSYMA, if they are not identical.

The file for the age-dependent consumption contains the item 'consumption rates in age steps of one year of life' (see Table 8 on page 4-9). This information is in general not available directly, but must be obtained from available data for different age groups. It is up to the user whether this is done by some reasonable interpolation between the values for the age groups, or by simply using the value for one age group for all ages between the lower and upper age limit of the corresponding group.

By historical reasons, the file structure of the risk conversion factors file is rather different as for the other ingestion data files (see Table 9 on page 4-9).

```

-----
Writing the file 1)
-----
WRITE(LUN) CFILID
WRITE(LUN) NNUK
DO ## INU=1, NNUK
WRITE(LUN) CNUKS, NUKING, NUKUFC, NUKUFD, TRAD12, F1INGA, F1INGI
## CONTINUE
-----
Meaning of variables
-----
CFILID : see "Frequently used variables"
NNUK   : number of nuclides contained in file
CNUKS  : name of individual nuclide (CHARACTER*8)
NUKING : sequence number of nuclide in file
NUKUFC : identification number of nuclide in COSYMA (normal nuclides) 2)
        identification number of mother in COSYMA ("daughters" ) 2)3)
NUKUFD : identification number of nuclide in COSYMA (all nuclides) 2)
TRAD12 : radioactive half-life (a)
F1INGA : assumed gut transfer factor for ingestion - adults
F1INGI : assumed gut transfer factor for ingestion - newborns
-----
Coding of CNUKS
-----
Character 01-02 two characters for the element name
                or one character for the element name followed by the
                blank character.
Character   03 the separator '-'
Character 04-06 mass number of the nuclide (right adjusted)
Character   07 the blank character.
                or M (for metastable) or D (for "daughter"3))
Character   08 the blank character.

Examples: 'SR- 90 ', 'I -131 ', 'CS-137 ', 'TE-129M ', 'AM-241D '

-----
Notes and rules
-----
1) File must include the names of every nuclide, for which data exist in
any of the ingestion data files.

2) NUKUFC=NUKUFD for all nuclides except "daughters" (see below).
If nuclide is not contained in the list of nuclides possible in COSYMA,
both numbers must be less or equal to zero.

3) Daughter means here a radionuclide originating from a decay chain after
being deposited. In the ingestion nuclides master file, the daughter
must have the postfix D and must come directly after the mother.
All data must be given normalized to a unit deposit of the mother.

```

Table 3. The ingestion nuclides file

"PROCESSING FILE PR" (# = 1) for calculations with COSYMA/COSING
"SPECIAL FILE SP" (# = 2) for COSING Preprocessors

Writing the file headers (both files)

```
WRITE(LUN#) CFILI#  
WRITE(LUN#) NNUK,NFOO,NBAN,NBYR2,TOFACC,MODTXT  
WRITE(LUN#) (FOONAM(IFO),IFO=1,NFOO),(BANNAM(IBA),IBA=1,NBAN),  
&          (BANTIM(IBA),IBA=1,NBAN),(TOFSET(IFO),IFO=1,NFOO)
```

Meaning of variables (both files)

CFILID, NNUK : see "Frequently used variables"

NFOO : number of foodstuffs contained in file

NBAN : number of bantimes contained in file

NBYR2 : address of t = 1 a (start of 2nd year) in banarray

TOFACC : day of release relative to the beginning of the year

MODTXT : model descriptor (CHARACTER*8(2); no coding rules)

FOONAM : names of foodstuffs (CHARACTER*8)

BANNAM : foodban times (the "banarray") - names (CHARACTER*8)

BANTIM : foodban times (the "banarray") - times (REAL)

TOFSET : offset of first contamination in food to time of release -| below

Rules for the file header data (both files)

- (1) The time zero of the time scale must be the time of the release.
- (2) The first time in the ban array must be T = 0.
- (3) BANTIM for bantimes < 1 a in years (e.g. 0.5 ≈ 183./365.)
BANNAM for bantimes < 1 a in days (e.g. ' 183 D')
BANTIM/BANNAM for bantimes ≥ 1 a in years (e.g. 10., ' 10 A')
- (4) TOFFSET is the approximate time after the release (in days), when **contaminated** food becomes available for consumption for the first time. TOFFSET can be greater or equal to 0; it is not used in COSYMA, but in some of the programs related to COSING.
Example: Release on January 1st, cows back on pasture on April 15,
-> TOFFSET = 105 for milk and beef.

Table 4. Activity levels in food files

Writing the data on file "PR"

DIMENSION SAN(MAXBAN,MAXFOO,4)

DO ### INU=1,NNUK

WRITE(LUN1) CNUKS,(((SAN(IBA,IFO,J),IBA=1,NBAN),IFO=1,NFOO),J=1,4)

CONTINUE

Meaning of "PR" - variables

CNUKS : see "Frequently used variables"

SAN : normalized activity levels in food

(,,1)	- activity levels	[(Bq/kg) / (Bq/m ²)]
(,,2)	- time integrals from t to t + 1 year	[(Bq*a/kg)/(Bq/m ²)]
(,,3)	- time integrals from 0 to t	[(Bq*a/kg)/(Bq/m ²)]
(,,4)	- time integrals from t to max.	[(Bq*a/kg)/(Bq/m ²)]

Rules for "PR" - data

SAN(1,,1) must contain the maximum value found for any of the bantimes

SAN(1,,2) must contain the maximum value found for any of the bantimes

Writing the data on file "SP"

PARAMETER (MAXTIM=200) *** MAXTIM should not be smaller than 200 ***

DIMENSION FCT2(MAXBAN,MAXFOO),FCT3(MAXTIM,MAXFOO)

NBZR2=NBZR2-1

DO ### INU=1,NNUK

IF(NOTZER.GT.0) THEN

WRITE(LUN2) CNUKS,NOTZER

IF(NBZR2.GT.1) WRITE(LUN2) ((FCT2(IBA,IFO),IBA=1,NBZR2),IFO=1,NFOO)

WRITE(LUN2) ((FCT3(ITI,IFO),ITI=1,NOTZER),IFO=1,NFOO)

END IF

CONTINUE

Meaning of "SP" - variables

CNUKS : see "Frequently used variables"

NOTZER : last year with non-zero data for all foodstuffs

FCT2 : integrals from t to 1 year for t < 1 a [(Bq*a/kg)/(Bq/m²)]

FCT3 : yearly integrals for years 1,2,...,NOTZER [(Bq*a/kg)/(Bq/m²)]

Table 4. Activity levels in food files (continuation)

"File 0" for COSING preprocessors

Writing the file "0"

PARAMETER [MAXIGT = "as many are available")
DIMENSION DPUI1(MAXORK,MAXAGE,MAXIGT)

WRITE(LUN) CFILID
WRITE(LUN) NNUK,NORK,NAGE,NIGT
WRITE(LUN) (ORKNAM(IOR),IOR=1,NORK),(AGENAM(IAG),IAG=1,NAGE),
& (IAGTIM(IAG),IAG=1,NAGE),(IGTTIM(IGT),IGT=1,NIGT)

DO ### INU=1,NNUK
WRITE(LUN) CNUKS,(((DPUI0(IOR,IAG,IGT),IOR=1,NORK),
& IAG=1,NAGE),IGT=1,NIGT)
CONTINUE

Meaning of variables in file "0"

CFILID, CNUKS, NNUK, NORK, ORKNAM, AGENAM
: see "Frequently used variables"
NAGE : number of age groups
IAG : index of an age group
IAGTIM : lower age boundary of each group (e.g. 15 for (15a-19a) group)
NIGT : number of time steps after one single intake
IGT : index of a time step after the single intake
IGTTIM : time belonging to index IGT
DPUI0 : (cumulative) dose per unit intake [Sv/Bq (ingested)]
for age IAGTIM(IAG) at single intake after time IGTTIM(IGT)).

"File 1" for calculations with COSYMA/COSING

Writing the file "1"

DIMENSION DPUI1(MAXORK,MAXAGE)

WRITE(LUN) CFILID
WRITE(LUN) NNUK,NORK,NAGE
WRITE(LUN) (ORKNAM(IOR),IOR=1,NORK),(AGENAM(IAG),IAG=1,NAGE)

DO ### INU=1,NNUK
WRITE(LUN) CNUKS,((DPUI1(IOR,IAG),IOR=1,NORK),IAG=1,NAGE)
CONTINUE

Table 5. Dose-per-unit-intake files for ingestion

Meaning of variables in file "1"

CFILID, CNUKS, NNUK, NORK, NAGE, ORKNAM, AGENAM
: see "Frequently used variables"
DPUI1 : (cumulative) dose per unit intake [Sv/Bq (ingested)]
for age group IAG at single intake after time (70a-age at intake).

"File D" for COSING preprocessors

Writing the file "D"

PARAMETER (MAXJAG=100) **** MAXJAG should not be smaller than 96 ****
PARAMETER (MAXJGT=100) **** MAXJGT should not be smaller than 96 ****
DIMENSION JGTMAX(MAXJAG),DPUID(MAXJGT,MAXJAG)

WRITE(LUN) CFILID
WRITE(LUN) NNUK,NORK,NJAG,NJGT
WRITE(LUN) (ORKNAM(IOR),IOR=1,NORK)

DO ### INU=1,NNUK
WRITE(LUN) CNUKS
DO ### IOR=1,NORK
WRITE(LUN) ORKNAM(IOR),(JGTMAX(IAG),IAG=1,NJAG)
DO # JAG=1,NJAG
IF(JGTMAX(JAG).GT.0) WRITE(LUN),(DPUID(JGT,JAG),JGT=1,JGTMAX(JAG))
CONTINUE
CONTINUE
CONTINUE

Meaning of variables in file "D"

CFILID, CNUKS, NNUK, NORK, ORKNAM : see "Frequently used variables"
NJAG : maximum year of life
JAG : index of a year of life (age 0 - 1a <=> 1st year of life)
NJGT : maximum year after one single intake
JGT : index of a year after the single intake
DPUID : yearly dose per unit intake [Sv/Bq*a (ingested)]
for lifeyear JAG at single intake in year JGT after the intake.

For rules for NORK, ORKNAM and DPUI see the chapter
"Organs in the ingestion data files and in COSYMA/COSING"

Table 5. Dose-per-unit-intake files for ingestion (continuation)

Writing the file

```
DIMENSION  ARC(MAXOBS,MAXORG,MAXBAN,MAXFOO)
WRITE(LUN) CFILID
WRITE(LUN) NNUK,NBAN,NFOO,NORG,NOBS
WRITE(LUN) (BANNAM(IBA),IBA=1,NBAN),(FOONAM(IFO),IFO=1,NFOO),
&          (ORGNAM(IOR),IOR=1,NORG),(OBSNAM(IOB),IOB=1,NOBS)
DO ##2 IGE=1,2
DO ##1 INU=1,NNUK
WRITE(LUN) CNUKS,((((ARC(IOB,IOR,IBA,IFO),IOB=1,NOBS),
&                IOR=1,NORG),IBA=1,NBAN),IFO=1,NFOO)
##1 CONTINUE
##2 CONTINUE
```

Meaning of variables

CFILID, CNUKS, NNUK, NBAN, NFOO, NORG, NOBS, BANNAM, FOONAM, ORGNAM, OBSNAM
: see "Frequently used variables"
IGE=1 : Living generations
IGE=2 : Following generations
ARC : activity-risk coefficients [1/(Bq/m²)] for time OBSNAM(IOB)

Table 6. Activity-risk coefficients file for ingestion

Writing the file

```
DIMENSION  ADC(MAXBAN,MAXFOO,MAXAGE,MAXORK)
WRITE(LUN) CFILID
WRITE(LUN) NNUK,NBAN,NFOO,NAGE,NORK
WRITE(LUN) (BANNAM(IBA),IBA=1,NBAN),(FOONAM(IFO),IFO=1,NFOO),
&          (AGENAM(IAG),IAG=1,NAGE),(ORKNAM(IOR),IOR=1,NORK)
DO #### INU=1,NNUK
WRITE(LUN) CNUKS,((((ADC(IBA,IFO,IAG,IOR),IBA=1,NBAN),
&                IFO=1,NFOO),IAG=1,NAGE),IOR=1,NORK)
#### CONTINUE
```

Meaning of variables

CFILID, CNUKS, NNUK, NBAN, NFOO, NAGE, NORK
: see "Frequently used variables"
ADC : activity-dose coefficients [Sv/(Bq/m²)]

Table 7. Activity-dose coefficients file for ingestion

Writing the file

```
PARAMETER (NJAG=100)      *** NJAG should not be smaller than 96 ***  
DIMENSION FCR(MAXAGE,MAXFOO),FFCR(MXXAGE,MAXFOO)  
WRITE(LUN) CFILID  
WRITE(LUN) NFOO,NAGE,NJAG  
WRITE(LUN) (FOONAM(IFO),IFO=1,NFOO),(AGENAM(IAG),IAG=1,NAGE)  
WRITE(LUN) ((FCR(IAG,IFO),IAG=1,NAGE),IFO=1,NFOO)  
WRITE(LUN) ((FFCR(JAG,IFO),JAG=1,NJAG),IFO=1,NFOO)
```

Meaning of variables

CFILID, NFOO, FOONAM, AGENAM : see "Frequently used variables"
NAGE : number of age groups
IAG : index of an age group
FCR : food consumption rate for each age group IAG (kg/a)
NJAG : maximum year of life
JAG : year of life (age 0 - 1a <=> 1st year of life)
FFCR : food consumption rate for each year of life [kg/a]

Table 8. Age-dependent food consumption rates file

Writing the file

```
PARAMETER (MAXJAG= 94)    *** MAXJAG should not be smaller than 94 ***  
PARAMETER (MAXJGT=100)   *** MAXJGT should not be smaller than 96 ***  
DIMENSION RCF(MAXJGT,MAXJAG,MXXORG)  
WRITE(LUN) CFILID  
WRITE(LUN) NORG,NJAG,NJGT  
WRITE(LUN) (ORGNAM(IOR),IOR=1,NORG)  
DO ### IOR=1,MAXORG  
DO ### JAG=1,MAXJAG  
WRITE(LUN) (RCF(JGT,JAG,IOR),JGT=1,MAXJGT)  
### CONTINUE
```

Meaning of variables

CFILID, NORG, ORGNAM : see "Frequently used variables"
NJAG : maximum year of life
JAG : year of life when dose is received
NJGT : maximum year after dose reception
JGT : index of a year after the dose was received
RCF : risk conversion factor [1/Sv]
(Cumulative number of fatalities expected for a collective of individuals of age JAG receiving one single dose as a function of year JGT after the reception of the dose).

Table 9. Risk conversion factors file

5. FREQUENTLY USED VARIABLES AND ARRAYS

Table 10 lists the variables and arrays most frequently used in the text of this document and in the ingestion-related source codes:

LUN	number of logical input unit (values differ in COSYMA and COSING)
CFILID(10)	file identifier (CHARACTER*8)
CNUKS	name of individual ingestion nuclide in data file (CHARACTER*8)
NNUK	actual number of ingestion nuclides contained in data file (there is no limit for this number)
INU	index referring to an ingestion nuclide
AGENAM(MAXAGE)	names of age groups (CHARACTER*8)
MAXAGE	maximum number of age groups allowed in data file or code
NAGE	actual number of age groups contained in data file
IAG	index referring to an age group
BANNAM(MAXBAN)	names of foodban times (CHARACTER*8)
BANTIM(MAXBAN)	foodban times (REAL)
MAXBAN	maximum number of foodban times allowed in data file or code
NBAN	actual number of foodban times contained in data file
IBA	index referring to a foodban time
FOONAM(MAXFOO)	names of foodstuffs (CHARACTER*8)
MAXFOO	maximum number of foodstuffs allowed in data file or code
NFOO	actual number of foodstuffs contained in data file
IFO	index referring to a foodstuff
NIGNAM(MAXING)	names of ingestion nuclides in COSYMA code (CHARACTER*8)
NUKNAM(MAXING)	names of ingestion nuclides in COSING code (CHARACTER*8)
MAXING	maximum number of ingestion nuclides allowed in code
NING	actual number of ingestion nuclides considered in code
INU	index referring to an ingestion nuclide
OBSNAM(MAXOBS)	names of observation times in ARC files (CHARACTER*8)
MAXOBS	maximum number of observation times allowed in data file or code
NOBS	actual number of observation times contained in data file
IOB	index referring to an observation time
ORGNAM(MAXORG)	names of "risk" organs (CHARACTER*8)
MAXORG	maximum number of "risk" organs allowed in data file or code
NORG	actual number of organs contained in data file
IOR	index referring to an organ
ORKNAM(MAXORK)	names of "dose" organs (CHARACTER*8)
MAXORK	maximum number of "dose" organs allowed in data file or code
NORK	actual number of organs contained in data file
IOR	index referring to an organ

Table 10. List of frequently used variables and arrays

It can be seen from the table, that the names of all CHARACTER items either start with the letter C or end with the three characters NAM. For all other names, the predefined FORTRAN type declarations are in effect, i.e. names starting with the one of the letters I to N refer to INTEGER data, and the rest to REAL data.

Variables and arrays referring to bantimes, foodstuffs, nuclides, organs etc. always have a three or two letter abbreviation as a part of the name, for example BAN or BA, FOO or FO and so on.

All names starting with the three characters MAX represent constants which limit the *maximum* number of the corresponding item in any data file or source code referring to them. The values of these limiting parameters may be subject to change and are not given here; their current values can be found in the corresponding PARAMETER section of the COSYMA FORTRAN program. - The *actual* number contained in a data set or considered in a program is characterized by the three letter abbreviation for the item preceded by the letter N.

6. REFERENCES

- [1] C. STEINHAUER. UFOING: A program for assessing the off-site consequences from ingestion of accidentally released radionuclides. Karlsruhe, KfK-4475 (1988).
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- [3] ICRP. Recommendations of the International Commission on Radiological Protection. ICRP publication 26, Vol. 1 No. 3 (1977).
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