COMMISSION OF THE EUROPEAN COMMUNITIES

COLLECTIVE DOSE ASSESSMENT OF RADIOACTIVE EFFLUENTS: A COMPUTER TAPE LIBRARY APPLICABLE TO THE EC

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A procedure to estimate the radiological impact on the population of the European Community of radioactive effluent discharges

A computer tape library has been compiled and can be readily applied to enable calculations to be made of the collective dose in the population of the European Community from radioactive effluent discharges. The background to the development of the tape library and details of its contents, method of application and availability are summarised.

Background

A comprehensive methodology(1) to evaluate the radiological impact of effluents discharged in the normal operation of nuclear installations has been developed by the National Radiological Protection Board (UK) and the Commissariat à l'Energie Atomique (France). The methodology was developed within the framework of the research programme of the European Communities (EC) on plutonium recycle in light water reactors. It comprises a series of interlinked models which describe the transfer of radioactive materials through the various parts of the environment and enables the exposure of, and consequential health impact in, the affected population to be estimated.

Because of the wide interest shown in the methodology and its potential applications it was the subject of a Seminar organised by the Commission of the European Communities (CEC) and held in Luxembourg in May 1979. A number of requests were made during the Seminar for the methodology to be made more widely available to enable its application in a variety of circumstances.

(1) NRPB/CEA. "Methodology for Evaluating the Radiological Consequences of Radioactive Effluents Released in Normal Operations". Joint Report prepared by the National Radiological Protection Board (UK) and the Commissariat à l'Energie Atomique (France). CEC Report, Doc No V/3865/79-EN, FR, July 1979.

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To meet these requests the Commission placed a contract with the National Radiological Protection Board to develop a procedure whereby the methodology could be provided to other organisations in a form that could be readily applied. This has been accomplished by the compilation of a computer tape library containing a matrix of results which can be used to evaluate the radiological impact of effluent discharges.

The computer tape library and its method of application

The matrix of results in the tape library has been compiled from application of the methodology to a wide range of circumstances. It contains data on the dispersion of nuclides in the atmosphere and in various aquatic environments, the transfer of nuclides through various parts of the environment, dosimetry as well as details of the distributions of the population and of agricultural products in the EC. Consideration is given to some 95 nuclides for discharge to the atmosphere and 41 nuclides for discharge to the aquatic environment. The contents of the tape library and its method of application are described in a recently published report[1].

Its application requires the specification by the user of various data which are particular to and characterise the actual discharge location. Subject to the specification of these data the tape library can be used to determine the collective dose to, and hence the radiological impact on, the population of the EC of:

- airborne discharges from any location in the EC
- liquid discharges to the marine environment from any location in the EC and
- liquid discharges into the Rhine and Rhône rivers from any location.

Availability

The report[1] describing the contents of the tape library has been published by the CEC and can be obtained, free of charge, from CEC, DG V/E/2, Office C-4/121, J. Monnet Building, LUXEMBOURG, Grand-Duchy of Luxembourg.

(1) Jones J.A. and Kelly G.N. "Collective Dose Assessment of Radioactive Effluents: a Computer Tape Library applicable to the EC". CEC Report Doc No V/4115/80-EN.

The tape library itself can be obtained, at a cost of £200 + VAT, on request from Dr. R.H. Clarke, Nuclear Assessments Department, National Radiological Protection Board, GB - HARWELL Didcot, Oxon OX11 ORQ.

The tape library can be written onto 9 track magnetic tape in several ways and the preferred format should accompany any request. The options are:

6250 bits per inch (bpi) with standard IBM labels
6250 bpi without labels
1600 bpi with standard IBM labels and
1600 bpi without labels.

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The International System of Units (SI) has been adopted throughout this report. The relationship between the SI units and previous units are shown in the table below.

Quantity	New named unit and symbol	In other SI units	Old special unit and symbol	Conversaion factor
Exposure	-	$C\ kg^{-1}$	röntgen (R)	1 $C\ kg^{-1}$ ~ 3876 R
Absorbed dose	gray (Gy)	$J\ kg^{-1}$	rad (rad)	1 Gy = 100 rad
Dose equivalent	sievert (Sv)	$J\ kg^{-1}$	rem (rem)	1 Sv = 100 rem
Activity	becquerel (Bq)	s^{-1}	curie (Ci)	1 Bq ~ 2.7 10^{-11} Ci

ABSTRACT

This report describes the contents of a computer tape library which can be used to estimate the collective dose to the population of the European Community (EC) from radioactive effluents released during the normal operation of nuclear installations. The tape library contains data on the dispersion, environmental transfer and dosimetry for a wide range of nuclides of radiological interest.

The method of application of the tape library is described and the information which must be provided by the user is specified. The library can be applied to evaluate the collective dose for releases to the atmosphere or to the marine environment from any location within the EC and for releases to the Rhine and Rhone rivers.

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1. INTRODUCTION

A comprehensive methodology to evaluate the radiological impact of effluent discharges to both the atmospheric and the aquatic environments has recently been developed by the National Radiological Protection Board and the Commissariat à l'Energie Atomique[1]. The methodology comprises a series of interlinked models which describe the transfer of radioactive materials through various sectors of the environment and enables the exposure of, and consequential health impact on, the affected population to be estimated. The methodology has since been applied to evaluate the differential radiological impact of effluent discharges when recycling plutonium in the Light Water Reactor Fuel Cycle[2].

The methodology was developed with the objective of being generally applicable. To assist in its wider application a matrix of the basic results, obtained when using representative values of the parameters in the various models, has been compiled. This matrix of results, when combined with further data specific to the particular discharge location, can be used to determine the radiological health impact on the population of the European Communities (EC) of :-

- routine airborne discharges from any location in the EC
- routine liquid discharges to the marine environment from any location within the EC
- routine liquid discharges into the Rhine and Rhone rivers.

The matrix of results has been compiled on magnetic tape and is subsequently referred to as the "Tape Library". Its contents and mode of application are described in this report and only a brief summary is given of the various models and values of parameters adopted in the derivation of the data in the Tape Library as these are fully described in reference 1.

2. RADIOLOGICAL IMPACT AND COLLECTIVE DOSE EQUIVALENT

At the levels of individual dose equivalent typically encountered from the discharge of radioactive effluents during the normal operation of nuclear installations, consideration can be limited to the incidence of stochastic health effects in the exposed population. Stochastic effects are those for which the probability of occurrence, rather than their severity, is regarded as a function of dose equivalent without threshold. Given this assumption and the further assumption that the severity of the effect is independent of the dose equivalent received then according to the International Commission on Radiological Protection (ICRP)[3] the detriment to health is proportional to, and may be represented by, the sum of the dose equivalents in the exposed population, ie, the collective dose equivalent. The stochastic effects which must be taken into account in assessing health detriment are somatic effects in the exposed population and hereditary effects in its descendants; by far the most important somatic effect is the induction of cancer which may or may not prove fatal. The stochastic health effects which need to be considered can thus be divided into three broad categories:

- fatal cancers for which there is no current treatment that is effective

- non-fatal cancers for which treatment, if needed, is effective in preventing consequential fatality

- hereditary effects which occur in subsequent generations.

No single dosimetric quantity, that has had general application, is sufficient to enable the estimation of the three categories of health effects listed above. Recourse has therefore to be made to the use of several quantities; the number has been kept to the minimum consistent with the evaluation of the total number of health effects, and with the adoption of generally accepted dosimetric quantities. The manner in which this has been done is described below.

The International Commission on Radiological Protection[4] has defined the quantity effective dose equivalent, H_E, as

$$H_E = \sum_T w_T H_T \qquad ....(1)$$

where H_T is the dose equivalent in tissue T and
w_T is the weighting factor for each tissue and represents the ratio of the stochastic risk from irradiation of tissue, T, to that for the whole body when uniformly irradiated.

The weighting factors have been specified by the ICRP in Publication 26[3] and in their derivation the ICRP chose to consider the risk of fatal cancer in all body organs and tissues, apart from in skin, plus the hereditary effects in the first two generations. The effective dose equivalent may only be used to give a measure of the incidence of these particular health effects; the incidence of the remaining effects must be evaluated from other quantities. The incidence of fatal cancers in skin and of hereditary effects in subsequent generations can be evaluated from a knowledge of the dose equivalents in skin and gonads respectively. The incidence of radiation induced non-fatal cancers may be most important in the skin and thyroid. This incidence may be calculated from the dose equivalents in these organs.

The evaluation of the incidence of the total health effects in an exposed population therefore requires the estimation of both the collective effective dose equivalent and the collective dose equivalents in gonads, skin and thyroid. The data provided in the tape library are sufficient for the estimation of these dosimetric quantities.

A further important consideration in judging the significance of the collective dose equivalent in a population is its distribution in time. For the discharge of some long lived nuclides which may persist in the environment the dose may be delivered over extremely long periods, eg. thousands, or in some cases even millions of years. The data in the tape library therefore enable the temporal distribution of the collective dose equivalent to be determined.

3. DISCHARGES TO ATMOSPHERE

3.1 General

Radioactive material released to the atmosphere will be transported downwind and dispersed by the normal atmospheric mixing processes. As the radioactive plume travels downwind the exposed population will be irradiated by two principal routes: these comprise external irradiation by electrons and photons from the radioactive decay processes and inhalation of activity in the plume. Radioactive material will be removed from the plume during its transit by deposition processes which occur mainly by impaction of material in the plume with the underlying surface over which it is travelling. The plume is also depleted by washout caused by rain. This transfer of activity from the plume to the ground results in irradiation of the population by three further important routes: external irradiation by electrons and photons from the deposited activity, the inhalation of activity which is subsequently resuspended into the atmosphere and the transfer of activity through the terrestrial environment to foodstuffs which may be consumed by man.

An assessment of the exposure of the population from the release of radionuclides to the atmosphere must therefore take account of the dispersion of activity in, and its deposition from, the atmosphere as well as the subsequent behaviour of deposited nuclides in the terrestrial environment. The spatial and temporal distribution of nuclides released to the atmospheric and terrestrial environments may be combined with the same distributions of population and agricultural production to calculate the exposure of the population from both external radiation and from the intake of radionuclides by inhalation and ingestion. The main processes and pathways to man that need to be considered in evaluating the exposure of the population are illustrated schematically in figure 1. Models were developed in the original study[1] to describe the transfer of radionuclides through the different sectors of the environment.

The models have been applied using representative values of the various parameters to derive a matrix of basic results. This matrix can be used to evaluate the exposure of the EC population from the discharge of radionuclides to the atmosphere from any location in the EC, subject to the specification of parameters particular to the discharge location.

The matrix of results and its mode of application for the estimation of collective dose are described.

3.2 Estimation of collective dose

3.2.1 General Procedure

The collective dose equivalent, S, in an exposed population is defined as

$$S = \int_0^\infty H \, N(H) \, dH \qquad ....(2)$$

where H is the individual dose equivalent and
$N(H)dH$ is the number of people receiving a dose equivalent between H and $H + dH$

Equation (2) can be transformed into the following form which facilitates the numerical evaluation of collective dose from atmospheric discharges.

$$S = \iiint_{d,\theta,t} N(d,\theta,t) \; \dot{H}(d,\theta,t) \; dt \, d\theta \, dd \qquad \ldots\ldots.(3)$$

where $N(d,\theta,t)$ is the number of people at time t, at distance d, and azimuthal angle, θ, relative to the point of discharge,
and $\dot{H}(d,\theta,t)$ is the individual dose equivalent rate at d,θ,t.

The spatial distribution of the population and of the radioactive material in various parts of the environment will, in reality, be continuously varying functions of distance, d, and azimuthal angle θ, relative to the discharge point. These variations can be approximated in the manner indicated in Figure 2. The area surrounding the discharge point is divided into a number of annuli of varying radii; these annuli are further subdivided into a number of sectors of width Δθ. If the annular segments are chosen such that the variation in the population density and the activity concentrations in various environmental materials (and hence dose) over the whole segment is small the collective dose equivalent commitment in any segment can be evaluated as

$$S(d_j,\theta_{jj}) = \int_t N(d_j,\theta_{jj},t) \; \dot{H}(d_j,\theta_{jj},t)dt \qquad \ldots\ldots.(4)$$

where $N(d_j,\theta_{jj},t)$ is the population
and $\dot{H}(d_j,\theta_{jj},t)$ is the mean dose equivalent rate in the jth distance band and jjth angular segment

The spatial component of the integration of total collective dose equivalent commitment specified in equation (3) can thus be reduced to a summation over the various annular segments. The collective dose equivalent commitment becomes

$$S = \sum_j \sum_{jj} \int_t N(d_j, \theta_{jj}, t) \ \dot{H}(d_j, \theta_{jj}, t) dt \qquad \text{.......(5)}$$

If the magnitude of the population in each segment is assumed to remain constant over all time equation (5) reduces to

$$S = \sum_j \sum_{jj} N(d_j, \theta_{jj}) \int_t \dot{H}(d_j, \theta_{jj}, t) dt \qquad \text{.......(6)}$$

The selection of annular segments represents a compromise between minimising computational effort, the availability of appropriate site-specific meteorological data and ensuring that any error introduced into the estimation of the collective dose equivalent commitment on account of the approximation is not significant in comparison with other uncertainties in the overall assessment. The number of sectors is determined by the available meteorological data (see section 3.2.4c). The distances used in reference 1 are given in table 1 as guidance to the user.

The procedure described is adequate for those routes of exposure where the dose is determined by the location of the population (ie external radiation from the cloud and deposited activity together with inhalation of airborne activity). It requires modification for exposure by ingestion of foodstuffs since there is no a priori correlation between the location of the population and exposure from dietary intakes. This is a consequence of diet in general being obtained from various distributed sources remote from any individual. For this route of exposure an alternative approach is adopted based on the spatial distribution of foodstuffs produced in the EC, relative to the discharge location. These foodstuffs are assumed to be consumed within the EC and the collective dose equivalent commitment is given by

$$S = H_{ing}(i) \sum_k \int_d \int_\theta \int_t PA(d,\theta,t,k) \ CCK(i,d,\theta,t,k) \ dt \ d\theta \ dd \qquad \text{..(7)}$$

where $H_{ing}(i)$ is the committed dose equivalent per unit intake of nuclide, i, by ingestion

$PA(d,\theta,t,k)$ is the yield of agricultural product, k, at time, t, at a distance d and azimuthal angle θ relative to the discharge

$CCK(i,d,\theta,t,k)$ is the concentration of nuclide, i, in agricultural product, k, at time, t

The yield and concentration of activity in the various food products will also be continuously varying functions of distance d, and angle, θ, relative to the discharge. These variations can be approximated in the same manner as described previously for the population distribution, that is the subdivision into annular segments over which the yield and concentration of activity are assumed uniform.

If the agricultural practice and yields of the various foodstuffs in each segment are assumed to be constant over all time equation (7) can be reduced to

$$S = H_{ing}(i) \sum_k \sum_j \sum_{jj} PA(d_j,\theta_{jj},k) \int_t CCK(i,d_j,\theta_{jj},t,k)dt \quad ....(8)$$

The various quantities in equations (6) and (8) can be evaluated for each route of exposure from the matrix of results in the tape library thus enabling the collective dose in the exposed population to be determined. The procedure to be followed for this purpose is described.

3.2.2 Estimation of collective dose using the tape library

The procedure to be followed in the estimation of collective dose from atmospheric discharges when using data from the tape library is illustrated in Figure 3. Data to be obtained from the tape library are distinguished from those which are site specific and which must be provided by the user.

The principal steps in the calculation of collective dose from each nuclide from external irradiation and from inhalation directly from the cloud and of resuspended activity are :

- calculate the air concentration, deposition rate and cloud γ dose rate for a discharge at the specified height as a function of distance and atmospheric stability category (assuming a uniform wind rose)
- calculate the annual average air concentration, deposition rate and cloud γ dose rate as a function of distance in each sector

subject to the meteorological data particular to the site of interest (ie. joint frequency distributions of atmospheric stability categories and wind direction)

- calculate individual doses from each pathway of exposure from the annual average air concentrations, deposition rate and cloud γ dose rate as a function of distance and direction using the appropriate dosimetric data

- from the spatial variation of the individual doses and that of the population determine the collective dose.

The calculation of collective dose from the ingestion of foodstuffs is undertaken in a slightly different way. The first two steps are identical to those described above; the remaining steps are:

- calculate the time integral of activity in unit mass of each foodstuff as a function of distance and direction using the annual average deposition rate and the air concentration previously calculated and data from the food chain models in the library

- calculate the collective intake of each nuclide as the product of the time integral of activity in unit mass of each foodstuff and its yield summed over all distances and directions

- calculate the collective dose as the product of dose per unit activity ingested and collective intake

The steps outlined above give the collective doses for each nuclide from each route. These collective doses are then summed as appropriate.

Each of these steps and the estimation of the various quantities in equations (6) and (8) are described in detail for each route of exposure.

a) Annual average values of air concentration, deposition rate and cloud γ dose rate

The annual average ground level air concentration, $C(i,d_j,\theta_{jj})$, for the continuous release of a nuclide, i, in the jth radial band and jjth angular segment is given by

$$C(i,d_j,\theta_{jj}) = N_s Q_o(i) \sum_c X_o(i,c,d_j)\ f(\theta_{jj},c) \qquad ....(9)$$

where C is the annual average air concentration (Bq m^{-3})

N_s is the number of sectors of width $\Delta\theta$ in the wind rose where $\Delta\theta = \frac{360^o}{N_s}$

$Q_o(i)$ is the release rate of nuclide i, (Bq s^{-1}) during the year

$X_o(i,c,d_j)$ is the air concentration per unit release rate of nuclide i at a distance d_j in stability category, c, assuming a uniform wind rose (Bq m^{-3} per Bq s^{-1})

and $f(\theta_{jj},c)$ is the fraction of the time a particular stability category c occurs with the wind blowing into a sector of angular width $\Delta\theta$; $\sum_{jj}\sum_c f(\theta_{jj},c) = 1$

Similarly the annual average deposition rate, $W(i,d_j,\theta_{jj})$ and the annual average cloud γ dose equivalent rate $\dot{H}_\gamma(i,d_j,\theta_{jj})$ are given by

$$W(i,d_j,\theta_{jj}) = N_s Q_o(i) \sum_c G(i,c,d_j)\ f(\theta_{jj},c)\ (\text{Bq } m^{-2}\ s^{-1}) \quad .....(10)$$

$$\dot{H}_\gamma(i,d_j,\theta_{jj}) = N_s Q_o(i)\ F_c(i) \sum_c H_G(i,c,d_j)\ f(\theta_{jj},c)\ (\text{Sv } y^{-1}) \quad ..(11)$$

where $G(i,c,d_j)$ is the deposition rate per unit discharge rate of nuclide i in stability category c and at distance d_j and assuming a uniform wind rose (Bq m^{-2} s^{-1} per Bq s^{-1})

$H_G(i,c,d_j)$ is the cloud γ effective dose equivalent rate per unit discharge rate of nuclide i in stability category c and at distance d_j and assuming a uniform wind rose (Sv y^{-1} per Bq s^{-1})

and $F_c(i)$ is a modifying factor to take account of shielding afforded by buildings, etc.

The values of $X_o(i,c,d_j)$, $G(i,c,d_j)$ and $H_G(i,c,d_j)$ are contained in the tape library each for a large number of nuclides discharged in each stability category and as a function of distance. The remaining quantities, N_s, $Q_o(i)$ and $f(\theta_{jj},c)$ are particular to the discharge and its location and must be specified by the user. The modifying factor $F_c(i)$ must also be specified by the user. Its value depends on the fraction of the time spent indoors, the type of buildings being considered and the γ ray energy. A typical value is 0.5.

In addition to the effective dose equivalent, consideration must be given to the dose equivalents in the gonads, skin and thyroid in the estimation of radiological impact. Modifying factors are contained in the library to enable these organ doses to be determined from the matrix of effective dose equivalents from cloud γ irradiation, $H_G(i,c,d_{jj})$, given in the library for each isotope.

b) <u>Estimation of exposure from external irradiation and inhalation of activity</u>

The annual average air concentrations, deposition rates and cloud γ dose rates as a function of distance and direction are the basic quantities used in the estimation of individual doses by each of the following routes :

- external β and γ radiation from the cloud
- inhalation of the cloud
- external β and γ radiation from deposited activity
- inhalation of resuspended activity

Each of these routes is considered in turn below.

<u>External irradiation from the cloud</u>

The estimation of the cloud γ dose has already been discussed and is given by equation (11).

The annual average cloud β dose equivalent in skin, $\dot{H}_\beta(i,d_j,\theta_{jj})$ is obtained from the annual average air concentration as

$$\dot{H}_\beta(i,d_j,\theta_{jj}) = C(i,d_j,\theta_{jj})\ HB(i)\ B_c(i)\ (Sv\ y^{-1}) \qquad \text{.......(12)}$$

where HB(i) is the dose equivalent rate in skin from β irradiation from the cloud per unit air concentration of nuclide, i ($Sv\ y^{-1}$ per $Bq\ m^{-3}$)

and $B_c(i)$ is a modifying factor to take account of shielding afforded by clothes, buildings etc.

Values of HB(i) for a wide range of nuclides are contained in the tape library.

Inhalation of the cloud

The committed dose equivalent $HI(i,d_j,\theta_{jj})$ to an individual at d_j,θ_{jj} from inhalation is obtained from the annual average air concentration as

$$HI(i,d_j,\theta_{jj}) = C(i,d_j,\theta_{jj})\ B\ H_{inh}(i)\ (Sv) \qquad \text{.......(13)}$$

where B is the annual volume of air inhaled and is taken as 8030 $m^3\ y^{-1}$ for an adult,

and $H_{inh}(i)$ is the committed dose equivalent per unit intake of nuclide, i ($Sv\ Bq^{-1}$)

Values for $H_{inh}(i)$ for a large number of nuclides in various chemical forms are contained in the library for the effective dose equivalent and the dose equivalents in skin, gonads and thyroid.

External radiation from deposited activity

The external doses from β and γ irradiation are obtained from the annual average deposition rates as follows

$$HD_\beta(i,d_j,\theta_{jj},t) = W(i,d_j,\theta_{jj})\ F_\beta(i,t)\ B_g(i)\ (Sv) \qquad \text{.......(14)}$$

$$HD_\gamma(i,d_j,\theta_{jj},t) = W(i,d_j,\theta_{jj})\ F_\gamma(i,t)\ F_g(i)\ (Sv) \qquad \text{.......(15)}$$

where HD_β is the dose equivalent in skin from β irradiation

$H\dot{D}_\gamma$ is the effective dose equivalent from γ irradiation

$B_g(i)$ is a modifying factor to take account of shielding provided by clothing, buildings etc.

$F_g(i)$ is a modifying factor to take account of shielding provided by buildings etc.

$F_\beta(i,t)$ and $F_\gamma(i,t)$ are the integrals to time, t, of the dose equivalent rate in skin from β radiation and the effective dose equivalent rate from γ radiation, respectively, from nuclide i deposited at a rate of 1 Bq m^{-2} s^{-1} continuously for 1y on undisturbed land and assuming no shielding from buildings etc. (Sv per Bq m^{-2} s^{-1} continuously for 1 year).

The library contains a matrix of values for $F_\beta(i,t)$ and $F_\gamma(i,t)$ for integration times of 50, 100, 500 years and infinity. It also contains modifying factors to enable dose equivalents in other organs from γ radiation to be determined from the effective dose equivalent.

The values of $F_\gamma(i,t)$ included in the library were evaluated assuming that the activity deposited on a uniform flat surface and include the shielding provided by the soil for γ rays originating below the surface. No allowance is made for further shielding caused by an uneven surface. The value of the modifying factor $F_g(i)$ must be specified by the user taking account of the respective periods spent indoors and outdoors, the shielding afforded by the type of building structure of interest and the contribution to the dose from activity deposited on the interior surfaces of buildings.

Inhalation of resuspended activity

The committed dose equivalent from inhalation of resuspended activity to time, t, is obtained from the annual average deposition rate as

$$H_R(i,d_j,\theta_{jj},t) = IRS(i,d_j,\theta_{jj},t)\ \ H_{inh}(i)\ \ (Sv) \qquad ....(16)$$

where $IRS(i,d_j,\theta_{jj},t)$ is the intake to time, t, by inhalation in Bq and is given by

$$IRS(i,d_j,\theta_{jj},t) = \frac{1}{3.15\ 10^7}\ W(i,d_j,\theta_{jj})\ \ I_R(i,t)\ \ B\ \ (Bq) \quad ...(17)$$

where $I_R(i,t)$ is the integral to time, t, of the resuspended air concentration from nuclide i deposited at a rate of 1 Bq m^{-2} s^{-1} continuously for 1 year on undisturbed land (Bq s m^{-3} per Bq m^{-2} s^{-1} continuously for 1 year)

and $3.15\ 10^7$ is a conversion factor to allow for the different units of B and I_R.

The tape library contains a matrix of results for $I_R(i,t)$ for integration times of 50, 100, 500 years and infinity and the other quantities have previously been defined.

The individual doses evaluated as a function of d, θ, and t for each pathway of exposure correspond to the integral $\int \dot{H}(d_j,\theta_{jj},t)dt$ in equation (6). The collective dose is thus obtained as the summation over all annular segments of the product of the individual dose and population in each segment for each nuclide and pathway of exposure. The evaluation of the population in each annular segment is described in section 3.2.3d.

c) <u>Estimation of exposure from ingestion of contaminated foodstuffs</u>

The collective dose from ingestion of contaminated foodstuffs is determined in two steps, first the estimate of the activity in foodstuffs and second the collective dose from the ingestion of food assuming all food produced in the EC is also consumed there.

The integral, to time t, of the concentration of nuclide i in unit mass of vegetable product, k, produced at (d_j,θ_{jj}) is given by

$$CK(i,d_j,\theta_{jj},k,t) = W(i,d_j,\theta_{jj})\ \ CP_1(i,k,t)\ \ TD(i,k)\ (Bq\ y\ kg^{-1}) \quad ....(18)$$

and for unit mass of animal product, k, by

$$CK(i,d_j,\theta_{jj},k,t) = \{ W(i,d_j,\theta_{jj})\ CP_1(i,k,t) + C(i,d_j,\theta_{jj})\ CP_2(i,k,t)\}\ TD(i,k)\ (Bq\ y\ kg^{-1}) \quad ....(19)$$

where $CP_1(i,k,t)$ is the integral to time t of the concentration of nuclide i in unit mass of vegetable or of animal product (for intake via ingestion), k, for a deposit of 1 $Bq\ m^{-2}\ s^{-1}$ coninuously for 1y on undisturbed land ($Bq\ y\ kg^{-1}$ per $Bq\ m^{-2}\ s^{-1}$ continuously for 1y)

$CP_2(i,k,t)$ is the integral to time t of the concentration of nuclide i in unit mass of animal product, k, via inhalation for 1 year of activity in the atmosphere at unit air concentration ($Bq\ y\ kg^{-1}$ per $Bq\ m^{-3}$ maintained for 1y)

and $TD(i,k) = \exp(-\lambda_i\ T_k)$ where λ_i is the radioactive decay constant

and T_k the delay between harvest and consumption of the particular foodstuff.

The need for two terms in equation (19) for animal products is a consequence of intakes into the animal from ingestion of deposited activity and inhalatión of airborne activity, respectively.

A matrix of values of CP is contained in the tape library for potentially significant food products. Values for T_k must be specified by the user although some guidance on representative values is given in reference 1.

The collective intake to time t of activity from food product, k, produced in an annular segment (d_j,θ_{jj}) is given by

$$CCP(i,d_j,\theta_{jj},k,t) = CK(i,d_j,\theta_{jj},k,t)\ PA(d_j,\theta_{jj},k) \quad (Bq) \quad ....(20)$$

where $PA(d_j,\theta_{jj},k)$ is the annual yield of foodstuff k in the annular segment (d_j,θ_{jj}) assuming it all to be consumed by the EC population ($kg\ y^{-1}$)

The spatial distribution of the production of significant foodstuffs in the EC is contained in the tape library and enables values of PA to be determined for appropriate annular segments as described in section 3.2.3d. The collective intake to time t by the EC population of nuclide, i, from ingestion of food product, k, is obtained by summation over all annular segments; the collective dose equivalent is derived as the product of this intake and the committed dose equivalent per unit activity ingested and is given by

$$S(i,k,t) = H_{ing}(i) \sum_{j} \sum_{jj} CCP(i,d_j,\theta_{jj},k,t) \quad (Sv) \qquad ....(21)$$

where $S(i,k,t)$ is the collective dose equivalent from nuclide i, foodstuff k and integrated to time t (man Sv)

and $H_{ing}(i)$ is the committed dose equivalent per Bq ingested for nuclide i ($Sv\ Bq^{-1}$)

Values of $H_{ing}(i)$ are contained in the tape library for various chemical forms of the ingested nuclide; committed dose equivalents in skin, gonads and thyroid are given in addition to the committed effective dose equivalent.

The collective dose equivalent from nuclide i by ingestion requires summation over the various food products.

d) <u>Collective dose equivalent from ingestion of tritium and carbon-14</u>

An alternative procedure is used to evaluate the collective dose equivalent from the ingestion of tritium and of carbon-14. All food and water is assumed to be derived at the location of the individual. The carbon-14/carbon-12 ratio in ingested material is assumed equal to that in the atmosphere at the point of intake; similarly the tritium/hydrogen ratio in ingested material is assumed equal to that of atmospheric water vapour.

The individual effective dose equivalent at d_j,θ_{jj} is given by

$$H_E(i,d_j,\theta_{jj}) = K(i) \quad C(i,d_j,\theta_{jj}) \quad (Sv) \qquad ....(22)$$

where $K(i)$ is the annual effective dose equivalent for unit air concentration maintained for 1y (Sv y^{-1} per Bq m^{-3})

and is given by

$$K(i) = \frac{H_{ing}(i).\ M_{ing}}{\rho} \qquad ....(23)$$

where M_{ing} is the mass of carbon (or water) ingested per year (kg y^{-1})

and ρ is the mass of carbon (or water) per unit volume of air (kg m^{-3})

The values of $K(i)$ are 1.7 10^{-6} and 6.7 10^{-4} Sv y^{-1} per Bq m^{-3} for tritium and carbon-14, respectively. The dose equivalents in the various organs are the same as the effective dose equivalents for the respective nuclides.

The collective dose equivalent in the population is obtained by summation over all segments of the product of the dose equivalent and the population in each segment d_j, θ_{jj} (see equation (6)).

3.2.3 Contents of the tape library relating to atmospheric discharges

The contents of those files in the tape library relevant to the assessment of the radiological impact of atmospheric discharges are described. The library is written in card image format. The data items are identified by the symbols used in the previous section. The contents of the tape library have been evaluated using the models and values of the various parameters described in reference 1 which can be consulted for further details. The ordering of files on the tape and the file names used on labelled tapes are described in section 6.

a) Air concentration, deposition rates and cloud γ effective dose equivalent rates

Matrices of results are given for effective heights of release of 30, 60 and 100m for discharge in each of the Pasquill and Doury atmospheric stability classes. The data are contained in 6 files; each file refers to a combination of a release height and either the

Pasquill or Doury stability categories. The mean wind speed and mixing layer depth assumed for each stability category are given in table 2; values of other parameters relevant to this classification can be found in reference 1. The nuclides considered, together with the values of deposition velocity, washout coefficient and half-life assumed are listed in table 3.

Each file contains, for the release of 1 Bq s^{-1} of each nuclide

- air concentration $X_0(i,c,d)$ (equation (9))
- deposition rate $G(i,c,d)$ (equation (10))
- effective cloud γ dose rate $H_G(i,c,d)$ (equation (11))

as a function of distance and for release in each stability category and assuming a uniform wind rose. The format of these files is given in table 4. The ordering of nuclides in the 6 data files is not however the same.

b) Dosimetric data for the intake of radionuclides

The dosimetry file for the intake of radionuclides contains for each nuclide :-

- the committed effective dose equivalent and the committed dose equivalents in skin, gonads and thyroid per unit activity inhaled (H_{inh}) (equation (13)) and ingested (H_{ing}) (equations (21) and (22)) for each of the lung classes (Y,W or D) and gut transfer fractions (f_1) applicable to the nuclide in various chemical forms (see table 11 for the lung class and f_1 value for different chemical forms).
- the β dose equivalent rate in skin per unit air concentration, (HB)
- the ratio of the dose equivalents in skin, gonads and thyroid to the effective dose equivalent for external γ irradiation from the cloud and from deposited activity.

The format of the file is given in table 5. The ordering of nuclides in this file is not the same as in the other files relating to atmospheric releases.

c) Data file relating to deposited activity

This file contains, for each nuclide considered:-

- the time integrals of activity in unit mass of each foodstuff to 50, 100, 500 years and infinite time from the deposition of a nuclide at a rate of 1 Bq m^{-2} s^{-1} continuously for 1 year and the time integrals of activity in unit mass of animal products from inhalation by the animal of air at a concentration of 1 Bq m^{-3} for 1 year, $CP_1(i,k,t)$ and $CP_2(i,k,t)$ (equations (18) and (19))

- the time integrals of air concentration of resuspended activity to the same times, following the deposition of 1 Bq m^{-2} s^{-1} continuously for 1y, $I_R(i,t)$ (equation (17))

- the time integrals, to the same times, of effective γ dose equivalent and skin β dose equivalent from external irradiation from deposited activity for a deposition rate of 1 Bq m^{-2} s^{-1} continuously for 1 year, $F_\gamma(i,t)$ and $F_\beta(i,t)$ (equations (14) and (15)).

The format of this file is given in table 6. The foodstuffs for which data are given are summarised in Table 7.

d) Population and agricultural production data

The distributions of the population and agricultural production in the EC are given in the tape library on grids whose elements have areas of approximately 10^2 km^2 and 10^4 km^2 respectively. The grids are defined on a latitude-longitude co-ordinate system. The grid of 10^4 km^2 used to represent the spatial distribution of agricultural production comprises the areas indicated in figure 4 where each grid area occupies 1.5^0 of longitude, with the range of latitude being selected such that the area is approximately 10^4 km^2. The grid with areas of approximately 10^2 km^2 is used to represent the population distribution; this has been derived from the larger grid by dividing it into 100 smaller areas, the divisions being of equal length along the sides of the large grid areas.

The population and agricultural production grids are contained in the library in two separate files. The population distribution file contains, for each grid area with a non-zero population

- the latitude and longitude co-ordinates (square numbers),

- the population in the grid area.

The agricultural production data file contains, for each grid area with non-zero production

- the latitude and longitude co-ordinates (square numbers)

- the production rates of the agricultural products listed in table 7 in the order specified.

The files are ordered from south to north.

The format of these files is given in tables 8 and 9.

The co-ordinate system used is illustrated on figures 4 and 5 and the latitude co-ordinate of each 10^4 km^2 grid area is given in table 10. Note that with the identifying scheme used the smallest 10^2 km^2 square number is 010 rather than 001; further the grid area defined as having a latitudinal co-ordinate of, for example, -194 lies 6 '10km' squares north of the latitude for point -19 as defined in table 10.

The data contained in these grid formats need to be transformed into population in annular segments relative to the discharge point for the purposes of calculating collective doses using the procedure described in this report. The following approach can be used.

The distance and direction of any point from a site is most easily obtained by projecting the grid onto a map using a Polar Stereographic Projection with the origin at the site which has latitude θ_o and longitude λ_o. The co-ordinates of any other point on the earth's surface with latitude θ and longitude λ are first transformed to a co-ordinate system obtained by a double rotation from the original latitude-longitude system. The transformed co-ordinates of the point (θ',λ') are given by

$$\sin\theta' = \sin\theta\sin\theta_o + \cos\theta\cos\theta_o\cos(\lambda - \lambda_o)$$

$$\sin\lambda' = \frac{\cos\theta\sin(\lambda - \lambda_o)}{\cos\theta'} \qquad \text{.......(24)}$$

After projecting on the map the point has co-ordinates given by

$$X = 2R\tan\left(\frac{\pi}{4} - \frac{\theta'}{2}\right)\cos\lambda' \qquad \text{.......(25)}$$

$$Y = 2R\tan\left(\frac{\pi}{4} - \frac{\theta'}{2}\right)\sin\lambda'$$

where R is the radius of the earth (6370 km)

The distance and direction (d_j and θ_{jj}) of the grid area from the site are then given by

$$d_j^2 = X^2 + Y^2 \qquad \text{.......(26)}$$

$$\tan\theta_{jj} = Y/X \qquad \text{.......(27)}$$

The population and agricultural production in the grid area can then be assigned to the appropriate annular segment (see figure 2) for use when evaluating collective dose in each segment. If greater precision is required near the discharge point, the population etc in each grid region can be distributed between smaller areas assuming a uniform density in the original grid area.

3.2.4 Data to be provided by the user

In order to apply the results in the tape library, to a particular discharge the user must provide various data which characterise the discharge and its location. These data are identified in section 3.2.2 and in Figure 3 and are further summarised here for convenience.

a) Population and agricultural production

The user must derive the population and agricultural production of each foodstuff in each annular segment with respect to the discharge location from the grids of these quantities in the tape library. A method of doing this is outlined in Section 3.2.3.

The distances chosen by the user to characterise the population or agricultural production distributions may not be those at which results are given in the tape library. In this case air concentrations etc. at the required distances can be obtained from those in the tape library by suitable interpolation.

b) Data on discharge to atmosphere

The user must specify the following details of the discharge :-

(i) the discharge rate of each nuclide, Bq s^{-1} assumed continuous for 1 year

(ii) the chemical form of each nuclide so that the appropriate dosimetric data can be selected. This chemical form will determine the ICRP lung class (D, W or Y) for inhalation of nuclides and the gut transfer fraction, f_1 for ingested nuclides. Lung classes and f_1 values for different chemical forms of the nuclides in the library are given in table 11.

(iii) the effective height of the discharge, m. Data files are contained in the library for only 3 effective heights of release, 30, 60 and 100m, and that nearest the effective height of discharge should be chosen. In general the collective dose is not very sensitive to release height and any error introduced by this approximation will be small.

c) Meteorological data

The user must specify the frequency distribution, $f(\theta_{ij},c)$, with which the wind blows into a particular sector in a particular stability category for the discharge location considered.

3.2.5 Daughter products of discharged nuclides

Data contained in the library refer to the nuclide named and do not in general include contributions from daughter products. Any daughter products formed after discharge and which may be significant must be considered separately.

The library contains air concentrations, deposition rates and cloud γ dose rates from a number of potentially significant daughter products formed after discharge; these are identified in table 3. The estimation of air concentrations etc. for these daughter nuclides are undertaken in the same way as for discharged nuclides by assigning a discharge rate to them equal to that of the parent.

The library values of external β and γ dose from deposited activity include the contribution from any daughter products formed after deposition but the dose from deposition of the daughter formed in the air must be evaluated as if it were a discharged nuclide.

The library contains time integrals of resuspended concentration separately for a deposited nuclide and for its daughter formed after deposition. The dose from the daughter must be included so that equations (16) and (17) must be applied to both the parent and its daughter formed after deposition based on the deposition rate of the parent in equation (16).

The only nuclide for which the daughter formed after deposition was assumed to pass into a food chain was Pu-241. This must therefore be treated in the same way as described above for resuspension.

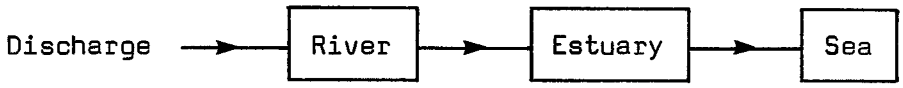
4. DISCHARGE TO THE AQUATIC ENVIRONMENT

4.1 Discharges to rivers

4.1.1 General

The radiological impact of the discharge of a nuclide to a river will vary markedly with the characteristics of the river. Consequently it has not proved possible, as it has in the case of atmosheric discharges, to develop a generic matrix of results that can be used to determine the impact of discharges to rivers from any location in the EC. Consideration is restricted in the tape library to two rivers, the Rhine and the Rhone.

Activity discharged to a river may lead to the irradiation of man by a variety of routes which are illustrated in Figure 6. In determining the collective dose in the exposed population account must be taken not only of the exposure while activity is in the river water or its sediments but also of that which arises from the subsequent transfer of activity to the marine environment. The basic modules in the model developed in reference 1 to describe the transfer of activity through the awuatic environment to man, once discharged to a river, are shown below :



From these models the exposure of the EC population can be determined by each of the significant pathways. These comprise

- the consumption of drinking water taken from the river
- the ingestion of fish taken from the river
- the ingestion of terrestrial foodstuffs irrigated by river water
- external irradiation from activity attached to river bed sediment
- the ingestion of fish, crustacea and molluscs from the marine environment.

The representation of the estuary in the overall model is simplistic since its contribution to the total collective dose from river discharges is small. It is interfaced between the river and marine environment solely to enable the estimation of the transfer of activity from river sediments to sea-water.

4.1.2 Estimation of collective doses from discharges to the Rhine and Rhone

The models developed in reference 1 have been used to compile a matrix of results which enable the collective dose from discharges of activity into the Rhine or Rhone to be determined. The estimation of the collective dose is undertaken in two distinct steps : that which arises while the activity is being transported by the river water or its sediments and that which arises following the transfer of activity to the marine environment. The basic steps in the procedure are illustrated in Figure 7.

a) <u>Collective dose from activity in the river water and sediments</u>

Each river has been divided into a number of sections within which various characteristics of the river, eg. flow rate, sediment load, slope of the river bed, are assumed constant. This sub-division is illustrated in Figures 8 and 9 for the Rhine and Rhone, respectively.

Consideration has been given to the discharge of a wide range of radionuclides at the beginning of each section of both rivers. The matrix of results obtained comprises for each nuclide, for the discharge of 1 Bq s^{-1} continuously for 1y, the collective intake of activity from ingestion of river water, irrigated terrestrial food products and fish downstream of the discharge location and the collective dose from external irradiation from river bed sediments. The intake of irrigated foodstuffs is subdivided into green vegetables, root vegetables and cereals.

The collective dose S in pathway m for a discharge of nuclide i at the beginning of section n, due to ingestion of activity is given by

$$S(m,n,i,t) = Q_o\ (i)\ IC_R(m,n,i,t)\ H_{ing}\ (i)\ TD(i,m) \qquad ....(28)$$

where i indicates the nuclide considered

and where Q_o is the discharge rate (Bq s^{-1} for 1 year)

IC_R the integral to time t of the collective intake rate summed over all sections of the river including and downstream of section n.

H_{ing} the committed effective dose equivalent or committed dose equivalent in skin, thyroid or gonads as appropriate for unit activity ingested (Sv/Bq) and TD(i,m) = exp $(-\lambda_i T_m)$ where λ_i is the radioactive decay constant for nuclide i and T_m the delay between harvest and consumption of foodstuff m.

The collective dose from external irradiation from river bed sediments S(sed,i,m,t) is given by

$$S(sed,i,m,t) = Q_o(i)\ HS(i,n,t) \qquad ....(29)$$

where HS is the integral to time t of the collective effective dose equivalent rate from external irradiation from river bed sediments for unit release rate of nuclide i into section n.

The total collective dose is then obtained by summing over all nuclides and pathways.

The quantities $IC_R(m,n,i,t)$, HS(i,n,t) are given in the tape library for a discharge at the start of each river section. Collective doses in the other organs can be obtained from the effective doses and the ratios of organ dose to effective dose for irradiation from deposited activity which are contained in the library (see section 3.2.3b). The quantities H_{ing} are also given in the library (see section 3.2.3b).

The collective dose from pathways associated with the river can thus be evaluated subject to the specification of the quantity of activity discharged, the chemical form of each nuclide and the discharge location. For discharges from locations other than at the beginning of a section the collective dose can be obtained to an adequate approximation by linear interpolation with respect to distance between the collective dose appropriate to discharges at the start of the adjacent sections.

b) Collective dose from activity transferred from the river to the marine environment

A fraction of the activity discharged to the river will subsequently be transferred via the estuary to the sea. The quantity of activity transferred as a function of time has been evaluated for unit discharge at the beginning of each of the river sections and is also included in the tape library. It forms the basis of the estimation of the collective dose from marine pathways which must be taken into account in determining the total collective dose from discharges to rivers. The estimation of this component of the collective dose is summarised in section 4.2.3 in the context of direct discharges to the marine environment.

4.1.3 Contents of the tape library for the estimation of the collective dose from discharges to rivers

The library contains data for discharges at the beginning of each section of the Rhine and the Rhone for those nuclides listed in table 12. The Rhine and Rhone are divided into 8 and 9 sections respectively (see Figures 8 and 9) and a separate data file has been created for discharges into each section; there are therefore a total of 17 data files. The ordering of the files on the tape and the names used on labelled tapes are given in section 6. The data files are written in card-image format.

Each file contains for a release of 1 Bq s^{-1} of each nuclide continuously for 1y,

- the collective intakes of each nuclide $IC_R(m,n,i,t)$ from the whole river, by ingestion of drinking water, freshwater fish and irrigated green vegetables, root vegetables and cereals. The intakes from irrigation are given integrated to 5, 50, 100, 500 years and infinity following the start of the discharge. The intakes by consumption of freshwater fish and drinking water are assumed to occur within the period of the discharge (ie 1 year) (equation (28))

- the integral of the collective effective dose equivalent rate to the same five times, from external irradiation from river bed sediments HS(i,n,t) (equation (29))

- the activity passing into the sea in river water all of which is assumed to transfer within the first year ($Q_o^*(i)$ (equation (33))

- the activity passing to the sea after desorption from sediment integrated to 1, 5, 50, 100, 500 years and infinite time from the start of the discharge $(Q_0^*(i))$ (equation (33)).

The data specified above are sufficient for the estimation of the collective dose for discharges to the Rhine and Rhone. The following additional data are also included in the tape library :

- the average concentration, during the period of the discharge, in water plus suspended sediments and in water alone, and the time integral of activity in bottom sediments integrated to 5, 50, 100, 500 years and infinite time after the start of the discharge in each section of the river downstream of the source.

These are the basic data from which the collective intakes and doses for the whole river were derived. It thus enables revised estimates to be made of collective dose should the user wish to use, for example, different yields of fish in various sections of the river etc from those adopted in the models described in reference 1.

The format of these data files is given in table 13.

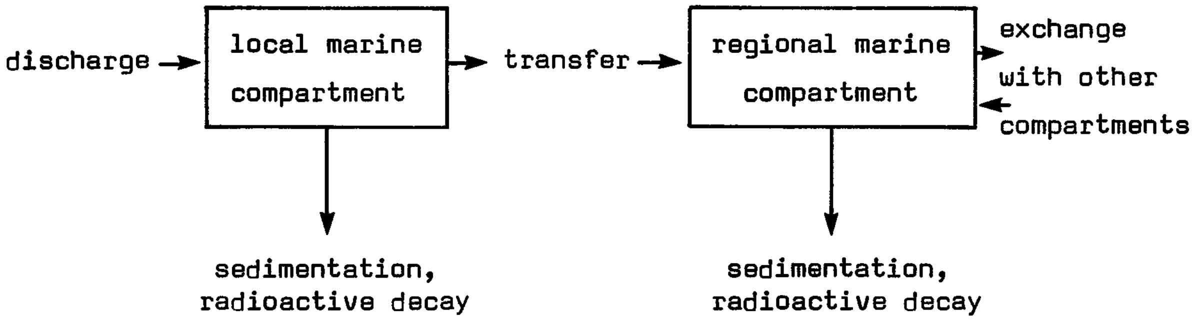
4.1.4 Data to be provided by the user

The data to be provided by the user are the discharge location and the quantities of the various nuclides discharged and the time delay between harvest and consumption. In addition the form in which the various nuclides may be ingested needs to be identified to assign the appropriate dose per unit intake to the ingested nuclide. The chemical form of the material may influence the fraction of activity crossing the GI tract; dosimetric data are contained in the library (see section 3.2.3b) for various chemical forms of nuclides.

4.2 Discharges to the marine environment

4.2.1 General

Activity may be discharged into the marine environment either directly or indirectly via a fresh-water body. In the latter case the environmental characteristics of the fresh-water system will influence the fraction of activity which eventually reaches the sea; this fraction can be evaluated in the manner described in section 4.2.3. For direct discharges the local environmental conditions determine the fraction of activity which becomes more widely dispersed and which, in general, contributes most significantly to the collective dose in the exposed population. For this reason the model chosen to characterise dispersion in the marine environment was subdivided into "local" and "regional" components which are then suitably interfaced. The local model is concerned with the estimation of water and sediment concentrations in the vicinity of the discharge and with the prediction of the fraction of the discharged activity which leaves the local area and becomes more widely dispersed in coastal waters bordering the EC and beyond. This more widespread dispersion is estimated using the regional model. The models are applied independently but subsequently interfaced in the manner indicated below to evaluate the collective dose for a discharge at a particular location.



In this way the results of the regional model (which are independent of the location of discharge over relatively large areas) can be readily combined with a number of local models each representing different local environmental conditions. In a similar manner the discharge from the river/estuary model is interfaced with the regional model.

The models enable the water concentrations in various sea areas to be determined as a function of time after discharge and take account of removal processes such as sedimentation and radioactive decay. These water concentrations can be used in association with concentration factors in marine species and fisheries statistical data to evaluate the collective intakes of activity by the EC population.

4.2.2 Estimation of collective doses from direct discharges to the marine environment

Regional marine models have been developed in reference 1 for the Northern European Waters and the Mediterranean and their general features are illustrated in Figures 10 and 11. The models have been used to compile a matrix of results which enable the collective dose to be evaluated for the discharge of liquid effluents to the marine environment from any location on the EC land mass when suitably interfaced with a model of the local environmental conditions. The basic steps in the procedure are illustrated in Figure 12.

The collective dose in the EC population from a discharge, $Q_o(i)$ into the marine environment is given by

$$S(m,i,t) = Q_o^*(i) \sum_m I_m(i,t)\ F_m^e\ TD(i,m)\ \ H_{ing}(i)\ \text{(man Sv)} \quad ......(30)$$

where $Q_o^*(i)$ is the rate of input into the regional marine compartment corresponding to an actual discharge to the marine environment of $Q_o(i)$ Bq s^{-1} assumed continuous for a year

$I_m(i,t)$ is the integral to time, t, of activity in foodstuff m (assumed to be consumed in the EC) for a discharge of 1 Bq s^{-1} continuously for 1y into a regional marine compartment. This value is obtained as the integral over time of the product of the yield and concentration of each marine foodstuff summed over all compartments in the regional marine model

m is the indicator of each foodstuff ie. fish, crustacea and molluscs

F_m^e is the edible fraction of each foodstuff

and $TD(i,m) = e^{-\lambda_i T_m}$ where T_m is the mean delay before consumption.

Values of $I_m(i,t)$ are contained in the tape library and the user must specify Q_o^*, T_m and F_m^e although guidance on values for F_m^e is given in reference 1.

The value of $Q_o^*(i)$ will depend on the environmental conditions local to the actual discharge. In general the residence time of activity in the local compartment will be short compared with the period of the discharge and the transfer of activity to the regional marine compartment can to an adequate approximation be considered as contemporaneous with the actual discharge. The rate of input into the regional marine compartment can then be obtained from the discharge rate by the following relationship

$$Q_o^*(i) = \frac{\lambda_r\, Q_o(i)}{\Lambda_e(i)} \qquad (Bq\ s^{-1}) \qquad \ldots\ldots\ (31)$$

where $\Lambda_e(i) = \lambda_r + \lambda_s(i) + \lambda(i)$

and $\lambda(i)$ is the radioactive decay constant, s^{-1}

$\lambda_s(i)$ is the rate of loss by sedimentation in the local compartment, s^{-1}

λ_r is the rate of renewal of water in the local compartment, s^{-1}

Values of λ_r and λ_s are particular to the discharge location and must be provided by the user. Considerable variation in these values is to be anticipated. Indicative values of these parameters are given in reference 1 for the four local environments considered. Substitution for Q_o^* from equation (31) into equation (30) enables the collective dose to be evaluated.

There will in addition be a contribution to collective dose from foodstuffs derived from the local marine compartment which is not taken into account in the procedure described. In general this will be negligible compared with that from the more widespread dispersion of activity but if necessary it can be estimated from local environmental conditions, eg. water concentrations, yields of sea food etc.

4.2.3 Estimation of collective doses from discharges to the marine environment via rivers

The collective dose from activity flowing into the sea after being discharged into a river is calculated using a modified version of equation (30). The modification is needed because of the extended period over which activity may be transferred to the sea, in particular that fraction which is desorbed from sediments at the estuarine interface between the river and sea. The values for $I_m(i,t)$ contained in the library were calculated assuming that the activity was discharged into a regional marine compartment at a constant rate for one year and that the discharge then ceased. The revised version of equation (30) applicable to a discharge over an extended period is

$$S(m,i,t) = F_e^m \, H_{ing}(i) \, TD(i,m) \sum_{\tau=0}^{t} Q_o^*(i,\tau) \, I_m(i,t-\tau) \qquad ....(32)$$

where t is the time over which the collective dose is to be integrated

τ the year after the start of the discharge

$I_m(i,t-\tau)$ the integral to time t of the activity in foodstuff m from activity transferred to the marine compartment at a mean rate of 1 Bq s^{-1} continuously for 1 year in the year τ

and $Q_o^*(i,\tau)$ the mean rate at which activity is transferred to the sea in year τ, Bq s^{-1} (continuously for 1 year).

The tape library contains values of I_m for a large number of times and values at other times can be obtained by interpolation. It also contains for discharge into each river section the total activity transferred to sea up to a range of times, A(i, t), which is given by

$$A(i, t) = \sum_{\tau=0}^{t} Q_o^*(i,\tau) \; 3.16 \; 10^7 \qquad ....(33)$$

4.2.4 Contents of the tape library for the estimation of the collective dose from discharges to the marine environment

The library contains data for discharges into each compartment of the regional marine model bordering the EC land mass for those nuclides listed in table 12. These are the same nuclides for which data relating to discharges into a river are given. The data for all nuclides for a discharge into a particular compartment are contained in one file. There are thus 14 files relating to the regional marine model for the northern European waters and two relating to the model of the Mediterranean sea. The integration times for which values are given for the two regions are not the same. The files are written in card-image format.

Each file contains, for each nuclide, the time integral of the activity in the EC catch (assumed to be consumed by the EC population) of fish, molluscs, crustacea and the total to a series of times for an input into the regional compartment of 1 Bq s^{-1} continuously for 1 year ($I_m(i,t)$ (equation (30)).

The compartments used are shown in figures 11 and 12.

The format of the files is given in table 14.

The doses per unit activity ingested are contained in a file described in section 3.2.3b.

4.2.5 Data which must be provided by the user

The user must specify the quantities of each nuclide discharged and values of the appropriate parameters required to characterise the local marine compartment. Judgements must also be made on the likely chemical forms in which nuclides may be ingested in order to select the appropriate dosimetric data. The delay between the fish catch and consumption and the edible fractions of the various foodstuffs must also be specified, although some guidance on the values for edible fraction has been given.(1)

5. DOSES FROM GLOBAL CIRCULATION

Four of the nuclides included in the library (^{3}H, ^{14}C, ^{85}Kr and ^{129}I), because of their long radioactive half-lives and mobility in the environment, become globally distributed following their initial dispersion and act as long term sources of exposure of the world's population. The tape library does not contain any data to enable the collective dose to the EC population to be evaluated. For completeness, however, the collective effective dose equivalent commitments to the EC population from the global circulation of these nuclides are summarised in Table 15 for initial discharges to both the atmosphere and aquatic environment. The doses from global circulation are essentially independent of the geographical location of the discharge within the EC. The temporal distribution of the collective effective dose equivalent commitments, and scaling factors to evaluate collective doses in skin, thyroid and gonads, are also given in Table 15. The models used to determine these doses are described in reference 1.

The collective doses in the world's population can be determined from the values given in Table 15 by scaling by the ratio of the world to the EC population (13.7) and assuming both populations to remain constant in magnitude over all time.

6. THE ORDERING OF THE DATA FILES IN THE TAPE LIBRARY

The files in the tape library are placed in groups :

- 6 files of atmospheric dispersion data
- the file of dosimetric data
- the file of foodchain and resuspension data
- 14 files of marine data relating to Northern Europe
- 2 files of marine data relating to the Mediterranean Sea
- 9 files of data for the river Rhone
- 8 files of data for the river Rhine
- the file of the population grid
- the file of the agricultural production grid

The ordering of files within each group is given in Table 16 which also gives the name of each file if the tape is written with a standard IBM label.

Each file is written in card images, ie. fixed length, blocked records with a logical record length of 80 bytes and a block size of 1680 bytes. The approximate number of card images in each file is given in Table 16.

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SYMBOLS USED FOR ATMOSPHERIC RELEASES

B	Annual volume of air inhaled
$B_c(i)$	Shielding factor for β irradiation from airborne activity
$B_g(i)$	Shielding factor for β irradiation from deposited activity
c	Indicator for atmospheric stability category
$C(i,d,\theta)$	Annual average air concentration
$CCK(i,d,\theta,t,k)$	Concentration of nuclide i in agricultural product k at time t
$CCP(i,d,\theta,t,k)$	Collective intake of activity from agricultural product k in a segment (d,θ) integrated to time t
$CK(i,d,\theta,t,k)$	Concentration of nuclide i in agricultural product k integrated to time t
$CP_1(i,k,t)$ $CP_2(i,k,t)$	Time integral of nuclide i in unit mass of agricultural product k for unit deposition rate and unit air concentration maintained for 1 year
d	Distance from the discharge point
$f(\theta,c)$	Fraction of time that wind blows into a particular sector in a particular atmospheric stability class
$F_c(i)$	Shielding factor for γ irradiation from airborne activity
$F_g(i)$	Shielding factor for γ irradiation from deposited activity
$F_\beta(i,t)$	Dose equivalent in skin to time t from β irradiation from deposited activity per unit deposition rate
$F_\gamma(i,t)$	Effective dose equivalent to time t from γ irradiation from deposited activity per unit deposition rate
$G(i,c,d)$	Deposition rate per unit discharge rate
H	Dose equivalent

$HB(i)$	Dose equivalent rate in skin from β irradiation from airborne activity per unit air concentration
$HD_\beta(i,d,\theta,t)$	Dose equivalent in skin integrated to time t from β irradiation from deposited activity
$HD_\gamma(i,d,\theta,t)$	Effective dose equivalent integrated to time t from γ irradiation from deposited activity
H_E	Effective dose equivalent
$H_G(i,c,d)$	Effective dose equivalent rate from γ irradiation from airborne activity per unit discharge
$HI(i,d,\theta)$	Committed dose equivalent from inhalation
$H_{ing}(i)$	Committed dose equivalent per Bq ingested
$H_{inh}(i)$	Committed dose equivalent per Bq inhaled
$H_R(i,d,\theta,t)$	Committed dose equivalent from resuspended activity inhaled to time t
H_T	Committed dose equivalent in tissue T
$H_\beta(i,d,\theta)$	Annual average dose equivalent in skin from β irradiation from airborne activity
$H_\gamma(i,d,\theta)$	Annual average effective dose equivalent from γ irradiation from airborne activity
i	Indicator of nuclide
$I_R(i,t)$	Integral to time t of resuspended air concentration per unit deposition
$IRS(i,d,\theta,t)$	Intake by inhalation of resuspended activity integrated to time t
j,jj	Indices for distance band and sector
$K(i)$	Effective dose equivalent rate for unit air concentration of H-3 or C-14

k	Indicator of agricultural product
N_s	Number of sectors in which population distributions etc. are given
$N(d,\theta,t)$	Number of people at distance d, azimuthal angle θ and time t
$N(H)dH$	Population whose dose equivalent lies between H and H + dH
n	Indicator of river section
$PA(d,\theta,t,k)$	Production rate at time t of agricultural product k
$Q_o(i)$	Discharge rate, assumed constant for 1 year
S	Collective dose equivalent
t	Indicator of time
$TD(i,k)$	Factor to correct for radioactive decay between harvest and consumption
T_k	Time delay between harvest and consumption
$W(i,d,\theta)$	Annual average deposition rate
w_T	Weighting factor in calculating effective dose equivalent
$X_o(i,c,d)$	Air concentration per unit discharge rate
λ_i	Radioactive decay coefficient
ρ	Mass of carbon or water per unit volume of air
θ	Indicator of angle
M_{ing}	Mass of carbon or water ingested per year

SYMBOLS USED FOR AQUATIC RELEASES

$A(i,t)$	Total activity transferred to sea to time t
F_m^e	Edible fraction of foodstuff m
$H_{ing}(i)$	Dose equivalent per Bq ingested
$HS(i,n,t)$	Collective effective dose equivalent from external irradiation from river sediments integrated to time t for unit discharge
i	Indicator of nuclide
$IC_R(m,n,i,t)$	Collective intake to time t for unit discharge from river products
$I_m(i,t)$	Activity in total catch of foodstuff m integrated to time t
m	Indicator of foodstuff type
n	Indicator of section of river containing a source
$Q_o(i)$	Discharge rate
$Q_o^*(i)$	Flow rate to regional marine compartment
S	Collective dose equivalent
t	Indicator of time
$TD(i,m)$	Factor to correct for radioactive decay between harvest and consumption
T_m	Time delay between harvest and consumption
λ_i	Radioactive decay coefficient
λ_r	Rate of renewal of water in local marine compartment
$\lambda_s(i)$	Sedimentation loss rate
τ	Time from the start of a discharge

Table 1

Radii used to specify annular bands used to characterise the spatial distribution of the population, agricultural production and activity concentration

Radial limits of annulus, km
0 - 1
1 - 2
2 - 3
3 - 5
5 - 7
7 - 10
10 - 15
15 - 20
20 - 35
35 - 50
50 - 70
70 - 100
100 - 200
200 - 300
300 - 450
450 - 700
700 - 1100
1100 - 1600
1600 - 2000
2000 - 2400
2400 - 3000

Table 2

The dispersion conditions for which data are given

a) Pasquill typing scheme

Category	Wind speed $m\ s^{-1}$	Depth of mixing layer m	Identifying No
A	1	2000	7
B	2	2000	8
C	5	1000	9
D	5	1000	10
E	3	200	11
F	1	200	12
C with rain	5	1000	9
D with rain	5	1000	10

b) Doury typing scheme

Dispersion condition	Wind speed $m\ s^{-1}$	Depth of mixing layer m	Identifying No
Poor	1, 2, 3	200	14
Normal	1, 2	2000	13
Normal	5	1000	13
Normal with rain	1, 2	2000	13
Normal with rain	5	1000	13

Table 3

The nuclides included in the atmospheric data files

NUCLIDE	PARENT	DAUGHTER (1)	DEP.VEL	WASH.COEFF	HALF LIFE (2)	
H-3		0	0.0	0.0	1.23E+01	y
C-14		0	0.0	0.0	5.70E+03	y
CR-51		0	5.00E-03	1.00E-04	2.77E+01	d
MN-54		0	5.00E-03	1.00E-04	3.12E+02	d
FE-55		0	5.00E-03	1.00E-04	2.70E+00	y
FE-59		0	5.00E-03	1.00E-04	4.51E+01	d
CO-58		0	5.00E-03	1.00E-04	7.10E+01	d
CO-60		0	5.00E-03	1.00E-04	5.28E+00	y
ZN-65		0	5.00E-03	1.00E-04	2.45E+02	d
NP239		0	5.00E-03	1.00E-04	2.30E+00	d
PU238		0	5.00E-03	1.00E-04	8.60E+01	y
PU239		0	5.00E-03	1.00E-04	2.44E+04	y
PU240		0	5.00E-03	1.00E-04	6.58E+03	y
PU241		0	5.00E-03	1.00E-04	1.50E+01	y
PU242		0	5.00E-03	1.00E-04	3.79E+05	y
AM241		0	5.00E-03	1.00E-04	4.58E+02	y
CM242		0	5.00E-03	1.00E-04	1.63E+02	d
CM244		0	5.00E-03	1.00E-04	1.76E+01	y
KR-85M		1	0.0	0.0	4.48E+00	h
KR-85		0	0.0	0.0	1.07E+01	y
KR-85	KR-85M	0	0.0	0.0	1.07E+01	y
KR-87		0	0.0	0.0	1.27E+00	h
KR-88		1	0.0	0.0	2.80E+00	h
KR-89(3)		0	0.0	0.0	3.16E+00	m
RB-86		0	5.00E-03	1.00E-04	1.87E+01	d
RB-88	KR-88	0	5.00E-03	1.00E-04	1.77E+01	m
RB-89		1	5.00E-03	1.00E-04	1.56E+01	m
SR-89		0	5.00E-03	1.00E-04	5.04E+01	d
SR-89	RB-89	0	5.00E-03	1.00E-04	5.04E+01	d
Y-91		0	5.00E-03	1.00E-04	5.85E+01	d
ZR-95		1	5.00E-03	1.00E-04	6.57E+01	d
NB-95		0	5.00E-03	1.00E-04	3.50E+01	d
NB-95	ZR-95	0	5.00E-03	1.00E-04	3.50E+01	d
MO-99		1	5.00E-03	1.00E-04	2.75E+00	d
TC-99M	MO-99	0	5.00E-03	1.00E-04	6.02E+00	h
RU-103		1	5.00E-03	1.00E-04	3.95E+01	d
RU/RH106		0	5.00E-03	1.00E-04	1.01E+00	y
RH103M	RU-103	0	5.00E-03	1.00E-04	5.69E+01	m
SB-125		1	5.00E-03	1.00E-04	2.74E+00	y
TE125M	SB-125	0	5.00E-03	1.00E-04	5.81E+01	d
TE127M		1	5.00E-03	1.00E-04	1.09E+02	d
TE-127	TE127M	0	5.00E-03	1.00E-04	9.34E+00	h
TE129M		1	5.00E-03	1.00E-04	3.36E+01	d
TE-129	TE129M	0	5.00E-03	1.00E-04	1.15E+00	h
TE131/M		1	5.00E-03	1.00E-04	3.00E+01	h
TE-132		1	5.00E-03	1.00E-04	3.25E+00	d
I-129		0	5.00E-03	1.00E-04	1.57E+07	y
J-129		0	5.00E-05	1.00E-04	1.57E+07	y
I-131	TE-131/M	0	5.00E-03	1.00E-04	8.04E+00	d
I-131		0	5.00E-03	1.00E-04	8.04E+00	d
J-131		0	5.00E-05	1.00E-04	8.04E+00	d
I-132		0	5.00E-0	1.00E-04	2.28E+00	h

cont............

Table 3 continued

I-132	TE-132	0	5.00E-03	1.00E-04	2.28E+00	h
J-132		0	5.00E-05	1.00E-04	2.28E+00	h
I-133		1	5.00E-03	1.00E-04	2.09E+01	h
J-133		1	5.00E-05	1.00E-04	2.09E+01	h
I-134		0	5.00E-03	1.00E-04	5.32E+01	m
J-134		0	5.00E-05	1.00E-04	5.32E+01	m
XE131M		0	0.0	0.0	1.20E+01	d
XE133M		1	0.0	0.0	2.23E+00	d
XE-133		0	0.0	0.0	5.28E+00	d
XE-133	XE133M	0	0.0	0.0	5.28E+00	d
XE-133	J-133	0	0.0	0.0	5.28E+00	d
XE-133	I-133	0	0.0	0.0	5.28E+00	d
XE135M		1	0.0	0.0	1.53E+01	m
XE-135		0	0.0	0.0	9.17E+00	h
XE-135	XE135M	0	0.0	0.0	9.17E+00	h
XE-137		0	0.0	0.0	3.84E+00	m
CS-134		0	5.00E-03	1.00E-04	2.08E+00	y
CS-135		0	5.00E-03	1.00E-04	3.01E+06	y
CS-136		0	5.00E-03	1.00E-04	1.30E+01	d
CS-137+D (6)		0	5.00E-03	1.00E-04	3.01E+01	y
CS-138		0	5.00E-03	1.00E-04	3.22E+01	m
BA-140		1	5.00E-03	1.00E-04	1.28E+01	d
LA-140		0	5.00E-03	1.00E-04	1.67E+00	d
LA-140	BA-140	0	5.00E-03	1.00E-04	1.67E+00	d
CE-141		0	5.00E-03	1.00E-04	3.25E+01	d
CE-144		1	5.00E-03	1.00E-04	2.84E+02	d
PR-144	CE-144	0	5.00E-03	1.00E-04	1.73E+01	m
KR-83M		0	0.00	0.00	1.83E+00	h
SR-90		1	5.00E-03	1.00E-04	2.82E+01	y
Y-90		0	5.00E-03	1.00E-04	2.67E+00	d
Y-90	SR-90	0	5.00E-03	1.00E-04	2.67E+00	d
TC-99		0	5.00E-03	1.00E-04	2.14E+05	y
I-135+D (7)		1	5.00E-03	1.00E-04	6.73E+00	h
J-135+D (7)		1	5.00E-05	1.00E-04	6.73E+00	h
XE-135	I-135+D	0	0.0	0.0	9.17E+00	h
XE-135	J-135+D	0	0.0	0.0	9.17E+00	h
XE-138		1	0.0	0.0	1.42E+01	m
CS-138	XE-138	0	5.00E-03	1.00E-04	3.22E+01	m
AR-41		0	0.0	0.0	1.83E+00	h
EU-154		0	5.00E-03	1.00E-04	8.50E+00	y
EU-155		0	5.00E-03	1.00E-04	4.96E+00	y
PM-147		0	5.00E-03	1.00E-04	2.62E+00	y
SB-124		0	5.00E-03	1.00E-04	6.03E+01	d

<u>Notes</u>

1) A 1 indicates that the daughter product of this nuclide is considered.
2) The units of half-life are minutes (m), hours (h), days (d) and years (y).
3) The decay chain KR-89, RB-89, SR-89 was represented by considering the release of 2 nuclides, KR-89 and Rb-89, the release rate of Rb-89 being equal to that of Kr-89 multiplied by the ratio of half-lives.
4) TE131/M represents TE-131M and its Te-131 daughter.
5) The element identified is J is organic iodine.
6) CS-137+D represents Cs-137 and is Ba-137m daughter.
7) I-135+D represents I-135 and is Xe-135m daughter.

Table 4

The format of the files containing air concentration, deposition rates and cloud γ dose

Meaning of variable	Symbol	Units	Format[1]
Number of nuclides in the file[2] Number of distances at which values are given[2] Number of stability categories[2] for which data are given Effective release height		 m	3(I5,10X), F10.2
For each nuclide Name of nuclide as specified in table 3 Name of parent (blank if this is a released nuclide) Identifier for daughter products = 1 if daughter considered, = 0 if not Deposition velocity Washout coefficient Half life Unit of half life[3]		 $m\ s^{-1}$ s^{-1}	2(A8,2X), I10, 3E10.2,A4
For each category and nuclide Category number[4] Name of category Wind speed Depth of mixing layer Identifier for rain, set = 1 for rain, = 0 for no rain		 $m\ s^{-1}$ m	I5,3X,3A4, 2F10.2,I10

cont'd

Table 4 Cont.

Meaning of variable	Symbol	Units	Format[1]
For each nuclide, category and distance(5,6)			
Distance	d_j	m	
Air concentration per unit release rate	$X_o(i,c,d_j)$	$Bq\,m^{-3}$ per $Bq\,s^{-1}$	
Deposition rate per unit release rate	$G(i,c,d_j)$	$Bq\,m^{-2}\,s^{-1}$ per $Bq\,s^{-1}$	8E 10.2
Effective cloud γ dose rate per unit release rate	$H_G(i,c,d_j)$	$Sv\,y^{-1}$ per $Bq\,s^{-1}$	

Notes

1) ----- indicates the end of a card image.
2) Data given for 9 Doury categories and 8 Pasquill categories (See Table 2) for 95 nuclides and 13 distances.
3) M, H, D or Y for minutes, hours, days or years respectively.
4) Category numbers are identified in table 2.
5) Two such records are written on a single card image.
6) Values are always given even when equal to zero.

Table 5

The format of the dosimetry file for the intake of Radionuclides[1]

Meaning of variable	Symbol	Units	Format[2]
Name of nuclide as specified in table 3 Number of lung classes for which inhalation dose is given (NL) Number of f_1 values[3] for which ingestion dose is given (NF)			A8, 2I5
For each lung class considered, if NL ≠ 0[4] Identifier of lung class[5] Effective, gonad, thyroid, skin dose equivalents per Bq inhaled	H_{inh}	Sv Bq^{-1}	I10, 4E10.2
For each f_1 considered, if NF ≠ 0[4] f_1 value Effective, gonad, thyroid, skin dose equivalents per Bq ingested	H_{ing}	Sv Bq^{-1}	5E10.2
β dose equivalent rate in skin per unit air concentration Ratio of gonad, thyroid and skin dose equivalents to effective dose equivalent from cloud γ irradiation[6] Ratio of gonad, thyroid and skin dose equivalents to effective dose equivalent from γ irradiation from deposited activity[6,7]	HB(i)	Sv y^{-1} per Bq m^{-3} Sv y^{-1} per Bq m^{-3}	7E 10.2

Cont....

Table 5 Cont.

Notes

1) Data are given for each of 96 nuclides.

2) ----- indicates the end of a card image.

3) f_1 is the fraction of material taken up by the GI tract.

4) These data are not given for some nuclides such as noble gases for which the remainder of the data are contained in the file.

5) 0, 1, 2 or 3 for unspecified (H-3 as HTO and C-14 as CO_2 only) or lung class D, W or Y respectively.

6) A zero is given for those nuclides with no γ rays.

7) A zero is given for those nuclides, such as noble gases, which do not deposit.

Table 6

The format of the files relating to deposited activity[1]

Meaning of variable	Symbol	Units	Format[2]
Name of nuclide (as specified in Table 3) Indicator for inclusion of data on daughter product (NDT)[3] Indicator for inclusion of food chain data (NDAT) Indicator for inclusion of food chain data for daughter (NDTG)[3]			A8,3I5
<u>If NDAT ≠ 0 for each of 13 food chains</u>[4,5] Contamination of food-stuff per unit deposition rate integrated to 4 times[6,7] Contamination of food-stuff due to daughter per unit deposition rate of parent at 4 times if NDTG ≠ 0[3]	CP(i,k,t)	Bq y kg^{-1} per Bq m^{-2} s^{-1} for 1y	8E10.2
Resuspended air concentration per unit deposition rate integrated to 4 times[8] Resuspended air concentration of daughter per unit deposition rate of the parent at 4 times[3] if NDT ≠ 0	$I_R(i,t)$	Bq s m^{-3} per Bq m^{-2} s^{-1} for 1 y	8E10.2
Effective γ dose equivalent from deposited activity per unit deposition rate to 4 times[8,9] Skin β dose equivalent from deposited activity per unit deposition rate to 4 times[8,9]	$F_\gamma(i,t)$ $F_\beta(i,t)$	Sv per Bq $m^{-2}s^{-1}$ for 1 y	8E10.2

cont'd

Table 6 Cont.

Notes

1) Data are given for each of 82 nuclides.

2) ----- indicates the end of a card image.

3) Refers to daughters formed after the deposition of the parent.

4) The food chains are, in order, green vegetables, grain products, root vegetables, sheep meat, sheep liver, cows meat, cows liver, and cows milk for animals inhaling followed by the five animal product routes for animals ingesting. The values for milk products are assumed equal to those for milk.

5) These values are not given if NDAT=0.

6) These variables refer to food contamination per unit air concentration for those routes involving animals inhaling when the units are Bq y kg^{-1} per Bq m^{-3} for 1 year. The values for milk are in units of litres not kg.

7) The times are always 50, 100, 500 years and infinity after the start of the discharge.

8) These values are always given.

9) These doses include the contribution from daughter products formed after deposition.

Table 7

FOODSTUFFS CONSIDERED IN THE TAPE LIBRARY

Fresh milk

Milk Products[1]

Cow's meat

Cow's liver

Sheep meat

Sheep liver

Grain products

Green vegetables[2]

Root vegetables

Note

1) Does not include butter as activity in milk is not assumed to transfer to the butter

2) Includes fruits

Table 8

The format of the population distribution file

Meaning of variable	Format
Longitude co-ordinate(1) Latitude co-ordinate(1) Population at this grid point	5(2I4, I8)(2)

Notes

1) Number of grid area as defined in figure 5.

2) There are 16132 grid areas with details of 5 areas written on each card-image. The last card-image has details for 2 areas.

Table 9

The format of the agricultural production distribution file

Meaning of variable	Format(2)
Longitude co-ordinate(1) Latitude co-ordinate(1) Production of each food-stuff(3) at this grid point	2I5,4E10.2, 5E10.2

Notes

1) Number of grid area as defined in figure 5.

2) There are 267 grid areas, the details of each area are written on two card-images.

3) Ordered as in table 7.

Table 10

Definition of the large grid areas (10^4 km^2) on the European Grid

Square Number	Degrees	Distance from Previous Parallel, km	Distance Between 2 Meridians km	Area (km^2)
-19	35.15		136.3	
-18	35.81	73.6	135.2	10000.7
-17	36.48	74.2	134.1	10002.5
-16	37.16	74.9	132.9	10004.3
-15	37.83	75.5	131.7	10006.1
-14	38.52	76.3	130.4	9994.9
-13	39.21	77.0	129.2	9997.1
-12	39.92	77.8	127.9	9999.4
-11	40.62	78.5	126.5	10001.8
-10	41.34	79.4	125.2	10004.2
-9	42.06	80.3	123.8	9994.3
-8	42.79	81.2	122.3	9997.2
-7	43.53	82.1	120.9	10000.2
-6	44.28	83.2	119.4	10003.3
-5	45.04	84.3	117.8	9994.7
-4	45.81	85.5	116.2	9998.5
-3	46.59	86.6	114.6	10002.3
-2	47.38	87.9	112.9	9994.9
-1	48.18	89.3	111.2	9999.6
0	49.00	90.6	109.4	10004.3
1	49.83	92.2	107.5	10002.9
2	50.68	93.9	105.6	9997.5
3	51.53	95.6	103.7	10002.1
4	52.41	97.4	101.7	9995.6
5	53.30	99.4	99.6	9998.8
6	54.22	101.5	97.5	10000.9
7	55.15	103.8	95.3	10001.9
8	56.11	106.3	93.0	10001.8
9	57.09	109.0	90.6	10000.3
10	58.10	112.0	88.1	9997.4
11	59.13	115.2	85.5	10001.6
12	60.20	118.8	82.8	10003.0
13	61.31	122.8	80.0	10001.7

Table 11

Lung classes and f_1 values appropriate to the nuclides considered

Element	Chemical form	Lung Class	f_1
H	Tritiated water		1.0
C	Carbon dioxide		1.0
Cr	Oxides and hydro-xides	Y	$1.0\ 10^{-1}$
	All other compounds	D	$1.0\ 10^{-1}$
Mn	Oxides, hydroxides, halides, nitrates	W	$1.0\ 10^{-1}$
	All other compounds	D	$1.0\ 10^{-3}$
Fe	Oxides, hydroxides,	W	$1.0\ 10^{-1}$
	All other compounds	D	$1.0\ 10^{-1}$
Co	Oxides, hydroxides,	Y	$5.0\ 10^{-2}$
	All other compounds	W	$5.0\ 10^{-2}$
Zn	Oxides, hydroxides, phosphate, nitrate	Y	$5.0\ 10^{-1}$
	Halides, sulphides	W	$5.0\ 10^{-1}$
	Sulphates	D	$5.0\ 10^{-1}$
Rb	All compounds	D	1.0
Sr	Titanate	Y	$1.0\ 10^{-2}$
	All other compounds	D	$3.0\ 10^{-1}$
Y	Oxides, hydroxides	Y	$1.0\ 10^{-4}$
	All other compounds	W	$1.0\ 10^{-4}$
Zr	Carbide	Y	$2.0\ 10^{-3}$
	Oxides, hydroxides	W	$2.0\ 10^{-3}$
	All other compounds	D	$2.0\ 10^{-3}$
Nb	Oxides, hydroxides	Y	$1.0\ 10^{-2}$
	All other compounds	W	$1.0\ 10^{-2}$
Mo	Sulphide, oxides, hydroxides	Y	$5.0\ 10^{-2}$(a)
	All other compounds	D	$8.0\ 10^{-1}$
Tc	Oxides, hydroxides, halides, nitrates	W	$8.0\ 10^{-1}$
	All other compounds	D	$8.0\ 10^{-1}$
Ru	Oxides, hydroxides	Y	$5.0\ 10^{-2}$
	Halides	W	$5.0\ 10^{-2}$
	All other compounds	D	$5.0\ 10^{-2}$
Rh	Oxides, hydroxides	Y	$5.0\ 10^{-2}$
	Halides	W	$5.0\ 10^{-2}$
	All other compounds	D	$5.0\ 10^{-2}$
Ag	All compounds	-(b)	$5.0\ 10^{-2}$
Sb	Oxides, hydroxides, sulphides, sulphates, nitrates, halides	W	$2.0\ 10^{-1}$
	All other compounds	D	$2.0\ 10^{-1}$
Te	Oxides, hydroxides,	W	$2.0\ 10^{-1}$
	All other compounds	D	$2.0\ 10^{-1}$
I	All compounds	D	1.0
Cs	All compounds	D	1.0
Ba	All compounds	D	$1.0\ 10^{-1}$
La	Oxides, hydroxides, fluorides	Y	$3.0\ 10^{-4}$
	All other compounds	W	$3.0\ 10^{-4}$
Ce	Oxides, hydroxides, fluorides	Y	$3.0\ 10^{-4}$
	All other compounds	W	$3.0\ 10^{-4}$
Pm	Oxides, hydroxides, carbides fluorides	Y	$1.0\ 10^{-4}$
	All other compounds	W	$1.0\ 10^{-4}$
Eu	Oxides, hydroxides, carbides, fluorides	Y	$3.0\ 10^{-4}$
	All other compounds	W	$3.0\ 10^{-4}$
Np	All compounds	W	$1.0\ 10^{-2}$
Pu	Dioxide	Y	$1.0\ 10^{-5}$
	All other compounds	W	$1.0\ 10^{-4}$
Am	All compounds	W	$5.0\ 10^{-4}$
Cm	All compounds	W	$5.0\ 10^{-4}$

Notes

a) Ingestion dose not included in the library for this f_1 value.

b) Inhalation dose not included in the library for Ag.

Table 12

Nuclides considered for aquatic discharges

Nuclide[1)]	Parent	Nuclide[1)]	Parent
3-H		129M-TE	
14C		132-TE	
51-CR		129-I	
54-MN		131-I	
55-FE		134-CS	
59-FE		136-CS	
58-CO		137-CS	
60-CO		144-CE	
65-ZN		154-EU	
89-SR		155-EU	
90-SR		239-NP	
90-Y		238-PU	
91-Y		239-PU	
95-ZR		240-PU	
95-NB*D	95-ZR	241-PU	
95-NB		241-AM*D	241-PU
99-TC		241-AM	
106-RU		242-PU	
110M-AG		242-CM	
125-SB		244-CM	
127M-TE			

Note

1) The nomenclature is that adopted in those files in the tape library associated with aquatic discharges.

Table 13

The format of the river data files

Meaning of variable	Symbol	Units	Format[1)]
Name of river Number of sections in the river[2)] Number of section where discharge is made Number of nuclides[3)]			A8,3I5
<u>For each nuclide</u> Name of nuclide as in table 12 Collective intake from drinking water integrated to infinity Collective intake from fish integrated to infinity	IC_R	Bq per Bq s^{-1} for 1 year	A8,2E10.2
Collective intake from irrigated green vegetables to 5, 50, 100, 500 years and infinity	IC_R	"	5E10.2
Collective intake from irrigated root vegetables to the same times	IC_R	"	5E10.2
Collective intake from irrigated cereals to the same times	IC_R	"	5E10.2
Collective effective dose equivalent rate from external irradiation integrated to the same times	HS	Man-Sv per Bq s^{-1} for 1 year	5E10.2
Integrated activity passing to the sea directly in water Integrated activity passing to the sea from sediments at 1, 5, 50, 100, 500 years and infinity	A A	Bq per Bq s^{-1} for 1 year	7E10.2

cont'd

Table 13 Cont.

Meaning of variable	Symbol	Units	Format[1)]
For each nuclide and each section downstream of the section containing the site			
Number of section			
Concentration of activity in water plus suspended sediments		Bq m^{-3} per Bq s^{-1} for 1 year	I10,7E10.2
Concentration of activity in filtered water		"	
Concentration of activity in sediments integrated to 5,50, 100, 500 years and infinity		Bq y kg^{-2} per Bq s^{-1} for 1 year	

Notes

1) ----- indicates the end of a card image.

2) 9 for the Rhone, 8 for the Rhine

3) Data are given for 41 nuclides.

Table 14

The format of the marine data files[1,2]

Meaning of variable	Symbol	Units	Format[1]
Name of regional compartment receiving the discharge Number of nuclides[2] Number of times at which data are given			3A8,2I5
For every nuclide Name of nuclide as specified in Table 11			A8
For every nuclide and every time Time since start of discharge Total activity in catch of fish, crustacea, molluscs and the total integrated to time t	t $I_m(t)$	y Bq per Bq s^{-1} for 1 year	5E10.2

Notes

1) ----- indicates the end of a card image.

2) Data are given for 41 nuclides.

Table 15

The collective effective dose equivalent commitment to the

EC population from global circulation

Nuclide	Environment to which discharge is made	Integral of the collective effective dose equivalent rate per unit release (man Sv per Bq s^{-1} continuously for 1 year)(1)			
		to 50y	to 100y	to 500y	to infinity
Krypton-85(2)	Atmosphere	5.29 10^{-19}	5.48 10^{-19}	5.48 10^{-19}	5.48 10^{-19}
Tritium(3)	Atmosphere & Aquatic	2,17 10^{-19}	2.18 10^{-19}	2.18 10^{-19}	2.18 10^{-19}
Iodine-129(4)	Atmosphere & Aquatic	2.52 10^{-15}	2.64 10^{-15}	3.55 10^{-15}	5.13 10^{-11}
Carbon-14(3)	Atmosphere	3.68 10^{-14}	4.16 10^{-14}	7.20 10^{-14}	4.45 10^{-13}
	Aquatic	1.73 10^{-14}	2.04 10^{-14}	4.16 10^{-14}	4.10 10^{-13}

Notes

1) Equivalent to a discharge of 3.15 10^{7} Bq.

2) Dose equivalents in gonads, thyroid and skin can be obtained by multiplying the effective dose equivalent by factors of 7.92 10^{-1}, 8.76 10^{-1}, 1.34 10^{2} respectively.

3) Dose equivalents in gonad, thyroid and skin are equal to the effective dose equivalent.

4) Dose equivalent in gonads, thyroid and skin can be obtained by multiplying the effective dose equivalent by 1.31 10^{-3}, 3.33 10^{1} and 2.42 10^{-3} respectively.

Table 16

The names and ordering of the files on the tape

Number	Name(1)	Description	Table in which format is specified	Approx length(3)
Atmospheric dispersion data files			4	
1	HOS3Ø.DATA	Pasquill categories, 30m stack		6500
2	HOS6Ø.DATA	" " 60m "		6500
3	HOS1ØØ.DATA	" " 100m "		6500
4	DOR3Ø.DATA	Doury categories 30m "		7200
5	DOR6Ø.DATA	" " 60m "		7200
6	DOR1ØØ.DATA	" " 100m "		7200
Dosimetry data file				
7	DOSIM.DATA	Dosimetric data	5	400
Terrestrial data file				
8	DEPACT.DATA	Foodchain and resuspension data	6	1200
Marine data files		Regional marine compartment receiving the discharge (see figures 10 and 11)	14	
9	MARINE.ISE.DATA	Irish Sea East		600
10	MARINE.ISW.DATA	Irish Sea West		600
11	MARINE.SCWAT.DATA	Scottish Waters		600
12	MARINE.ISS.DATA	Irish Sea South		600
13	MRINE.NEA.DATA	North East Atlantic		600
14	MARINE.BOB.DATA	Bay of Biscay		600
15	MARINE.IRWAT.DATA	Irish Waters		600
16	MARINE.BRCH.DATA	Bristol Channel		600
17	MARINE.ECW.DATA	English Channel West		600
18	MARINE.ECE.DATA	English Channel East		600
19	MARINE.NSS.DATA	Southern North Sea		600
20	MARINE.NSC.DATA	Central North Sea		600
21	MARINE.BALTIC.DATA	Baltic		600
22	MARINE.NSN.DATA	Northern North Sea		600
23	MARINE.WMED.DATA	Western Mediteranean		400
24	MARINE.EMED.DATA	Eastern Mediteranean		400
River data files			13	
25	RHONE.SECT1.DATA	Discharge into section 1 of the Rhone		440
26	RHONE.SECT2.DATA	" " " 2 " " "		440
27	RHONE.SECT3.DATA	" " " 3 " " "		370
28	RHONE.SECT4.DATA	" " " 4 " " "		330
29	RHONE.SECT5.DATA	" " " 5 " " "		290

cont...........

Table 16 continued

30	RHONE.SECT6.DATA	Discharge into section 6 of the Rhone		250
31	RHONE.SECT7.DATA	" " " 7 " " "		210
32	RHONE.SECT8.DATA	" " " 8 " " "		170
33	RHONE.SECT9.DATA	" " " 9 " " "		120
34	RHINE.SECT1.DATA	Discharge into section 1 of the Rhine		410
35	RHINE.SECT2.DATA	" " " 2 " " "		370
36	RHINE.SECT3.DATA	" " " 3 " " "		330
37	RHINE.SECT4.DATA	" " " 4 " " "		290
38	RHINE.SECT5.DATA	" " " 5 " " "		250
39	RHINE.SECT6.DATA	" " " 6 " " "		210
40	RHINE.SECT7.DATA	" " " 7 " " "		170
41	RHINE.SECT8.DATA	" " " 8 " " "		120
<u>Population and Agricultural files</u>				
42	POPGRID.DATA	Population distribution grid	8	3200
43	AGPROD.DATA	Agricultural production grid	9	530

<u>Note</u>

1) DSN used on tapes with a standard IBM label
2) Table describing file content of and format required to read the file
3) Approximate lenght of the file, number of card images

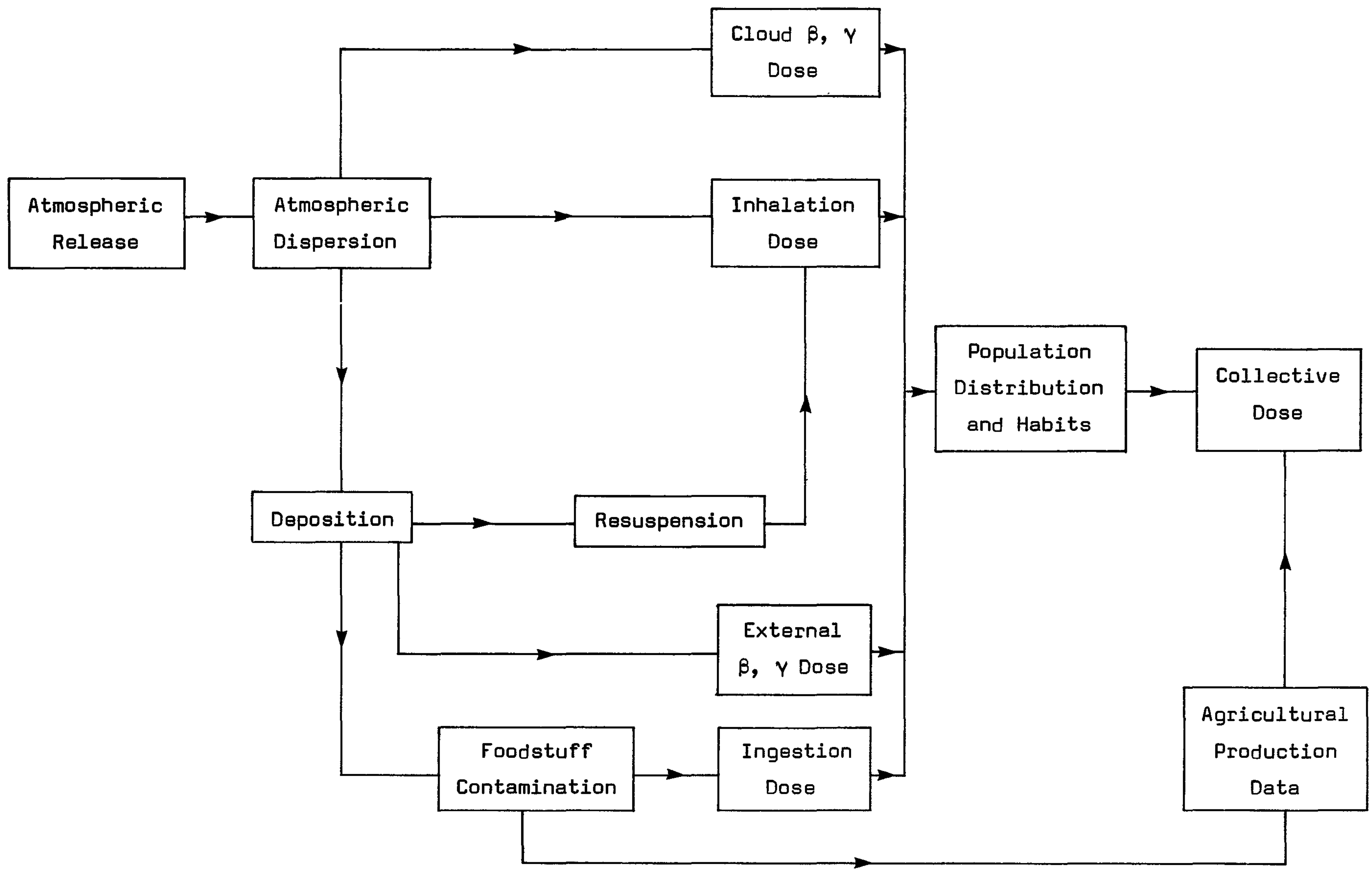
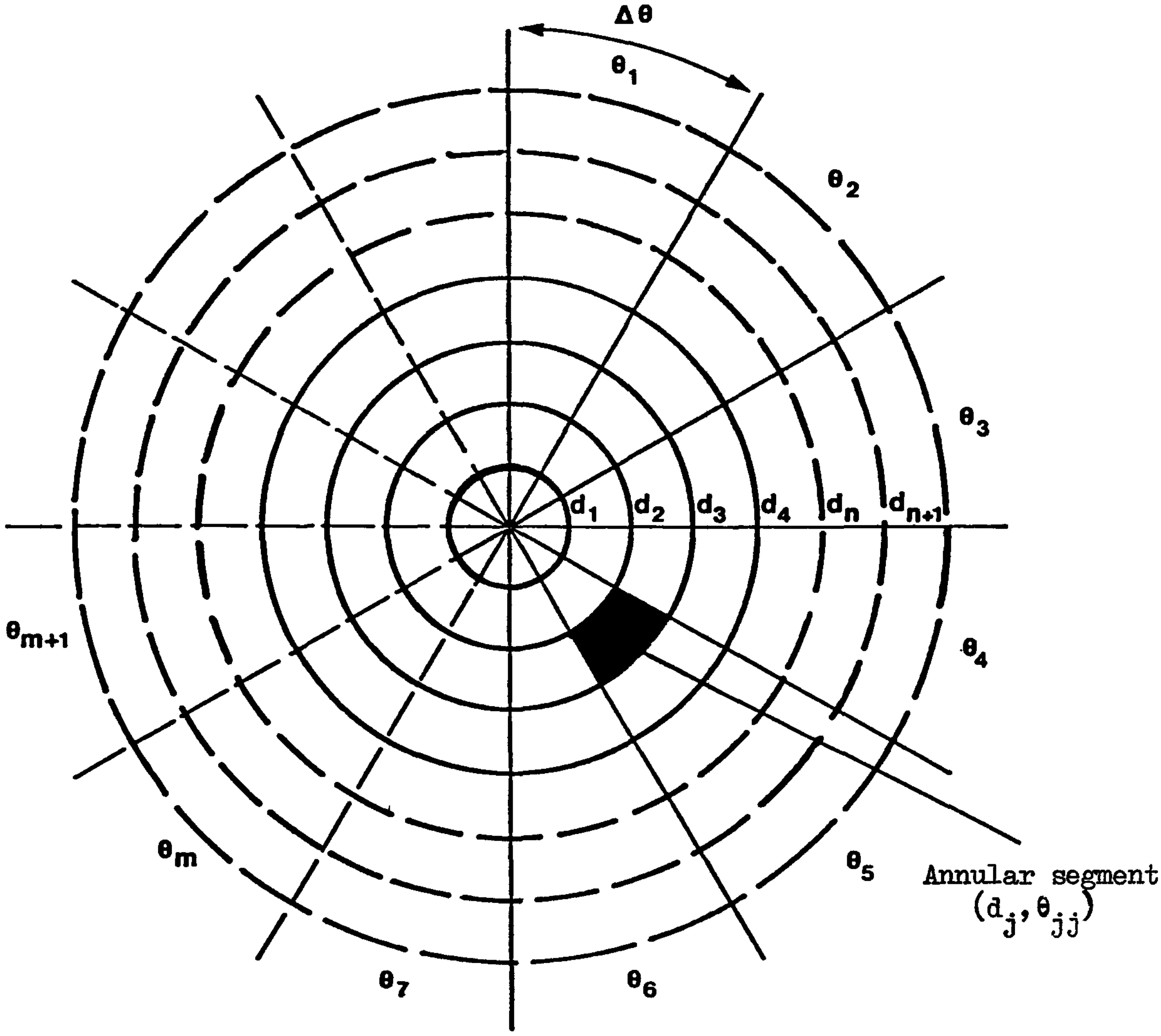


Figure 1. Schematic diagram of pathways to man considered for atmospheric releases



$\Delta\theta = \frac{360^\circ}{N_s}$ where N_s is the number of sectors

Figure 2. Illustration of the scheme of annular segments adopted to represent the spatial distribution of population and activity in various parts of the environment

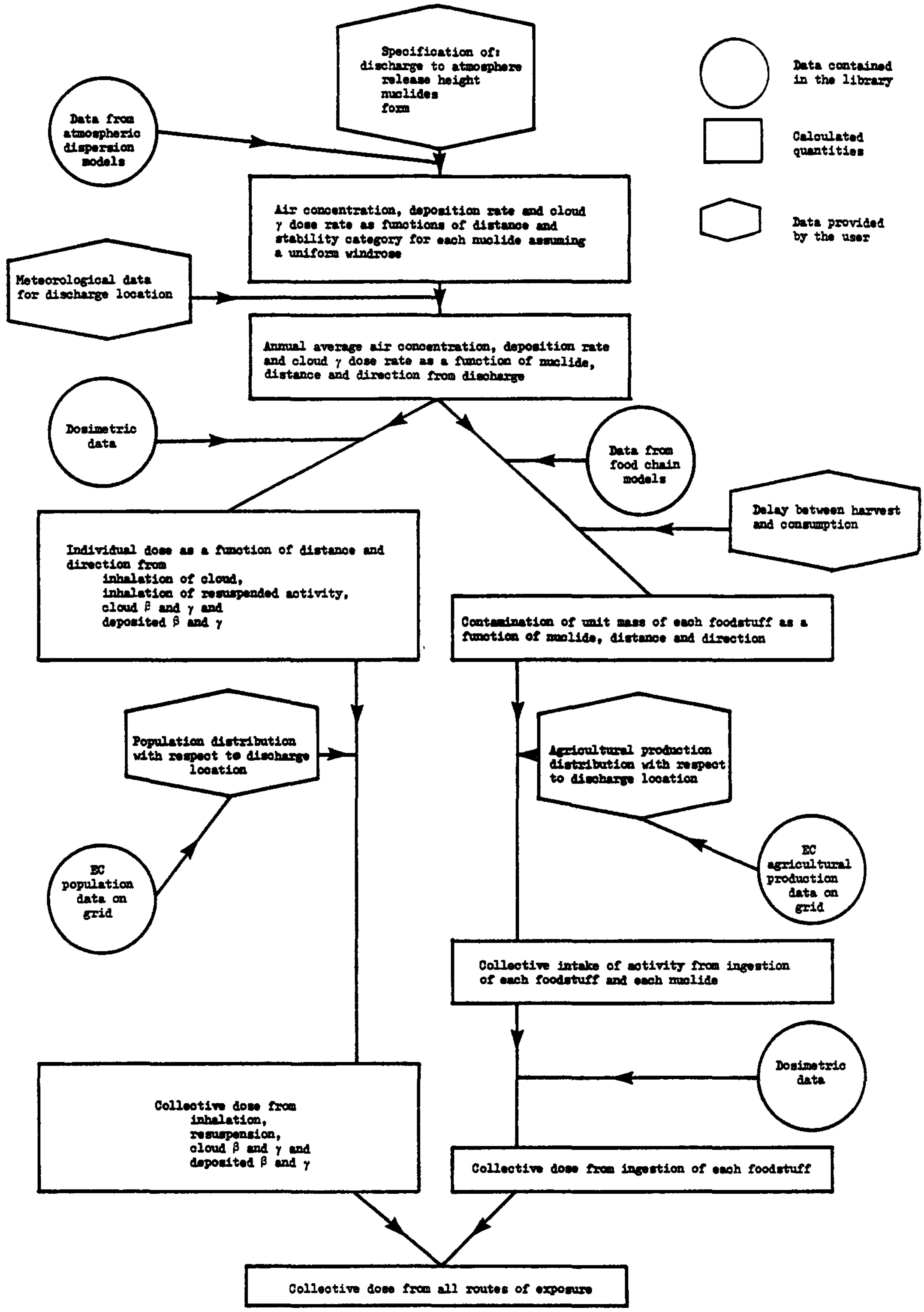


Figure 3. The scheme for calculating collective doses from atmospheric discharges

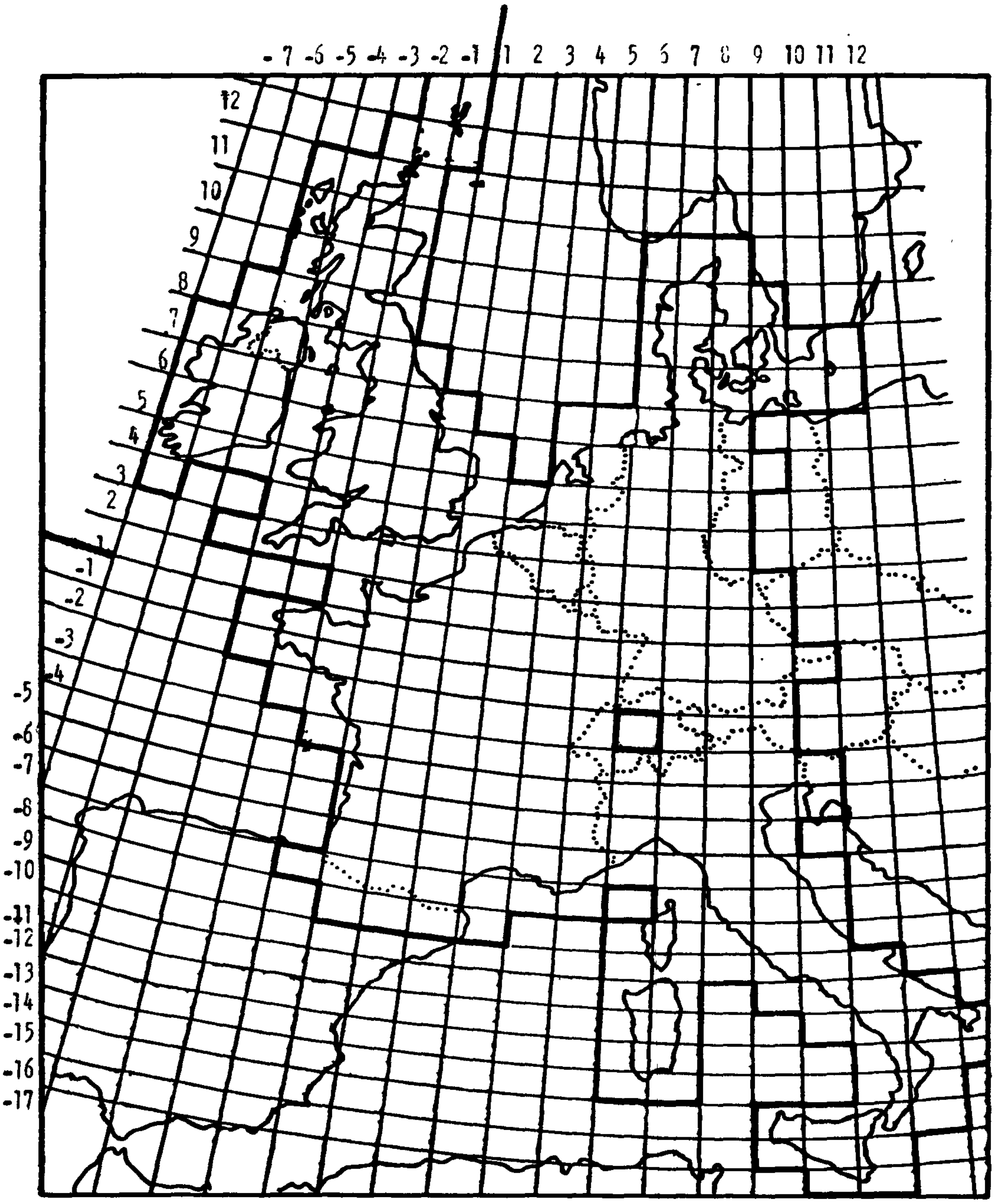


Figure 4. The grid system used for the 10^4 km^2 grid areas

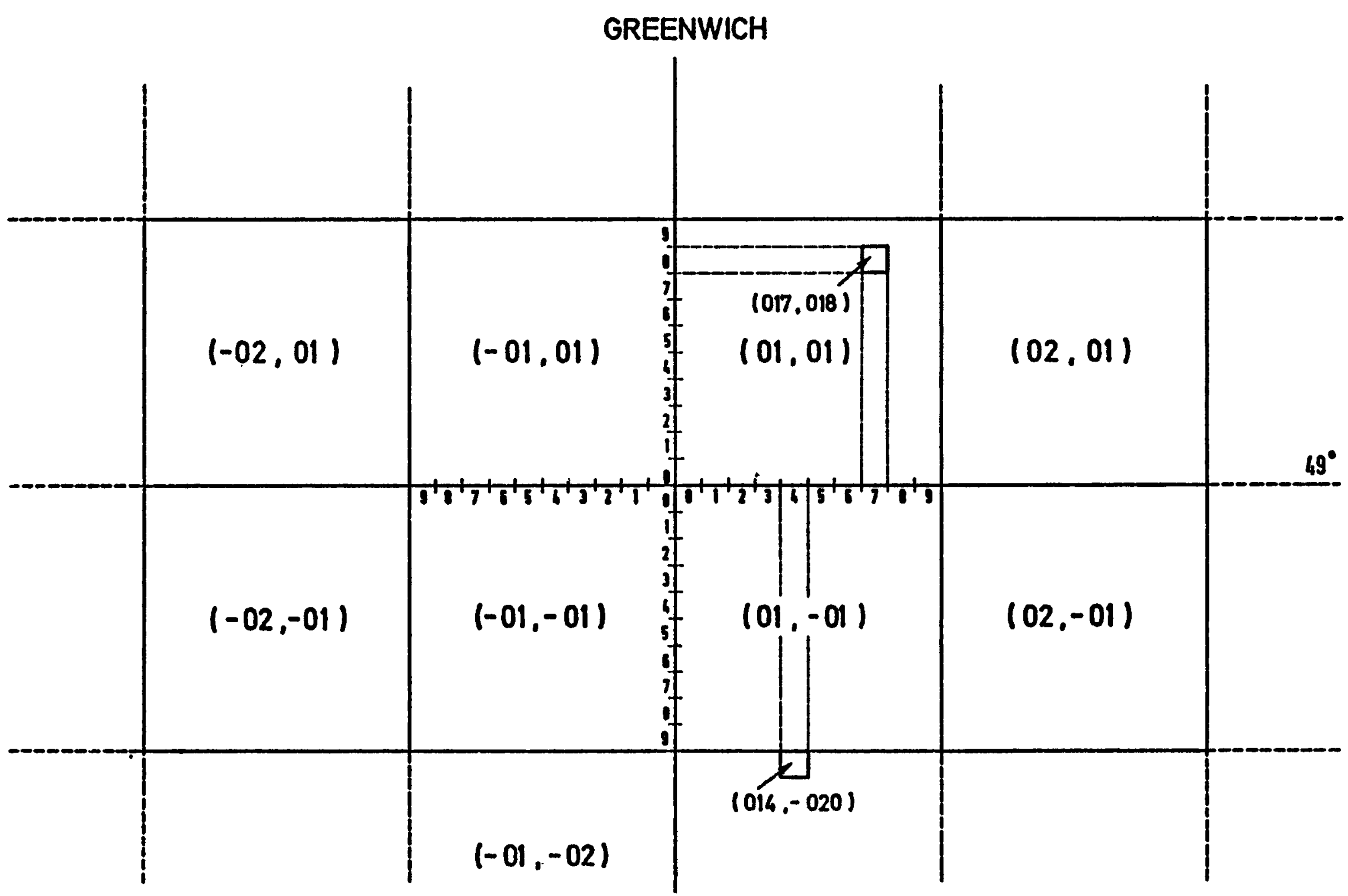


Figure 5. Representation of the squares forming the grid

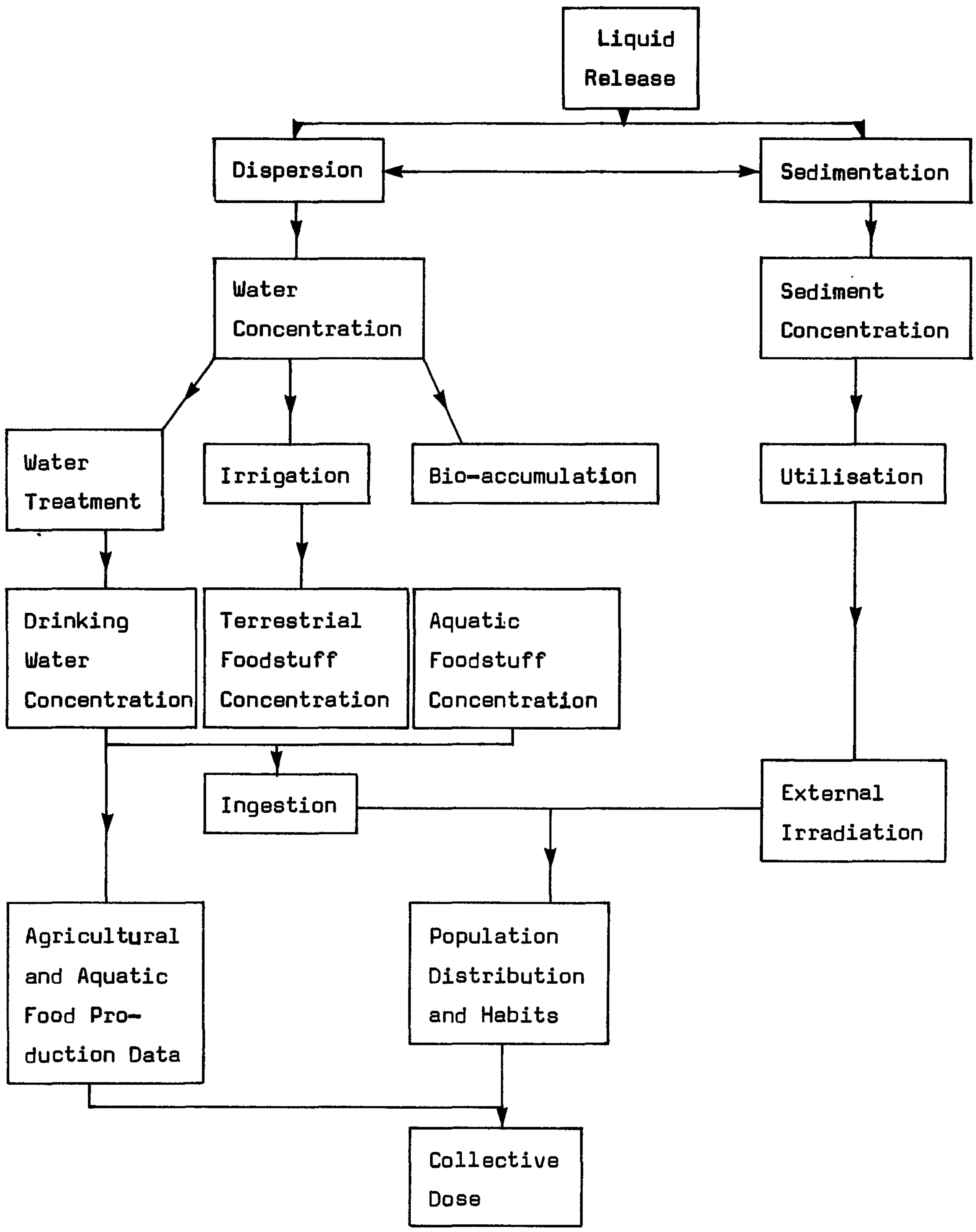


Figure 6. Aquatic pathways to man

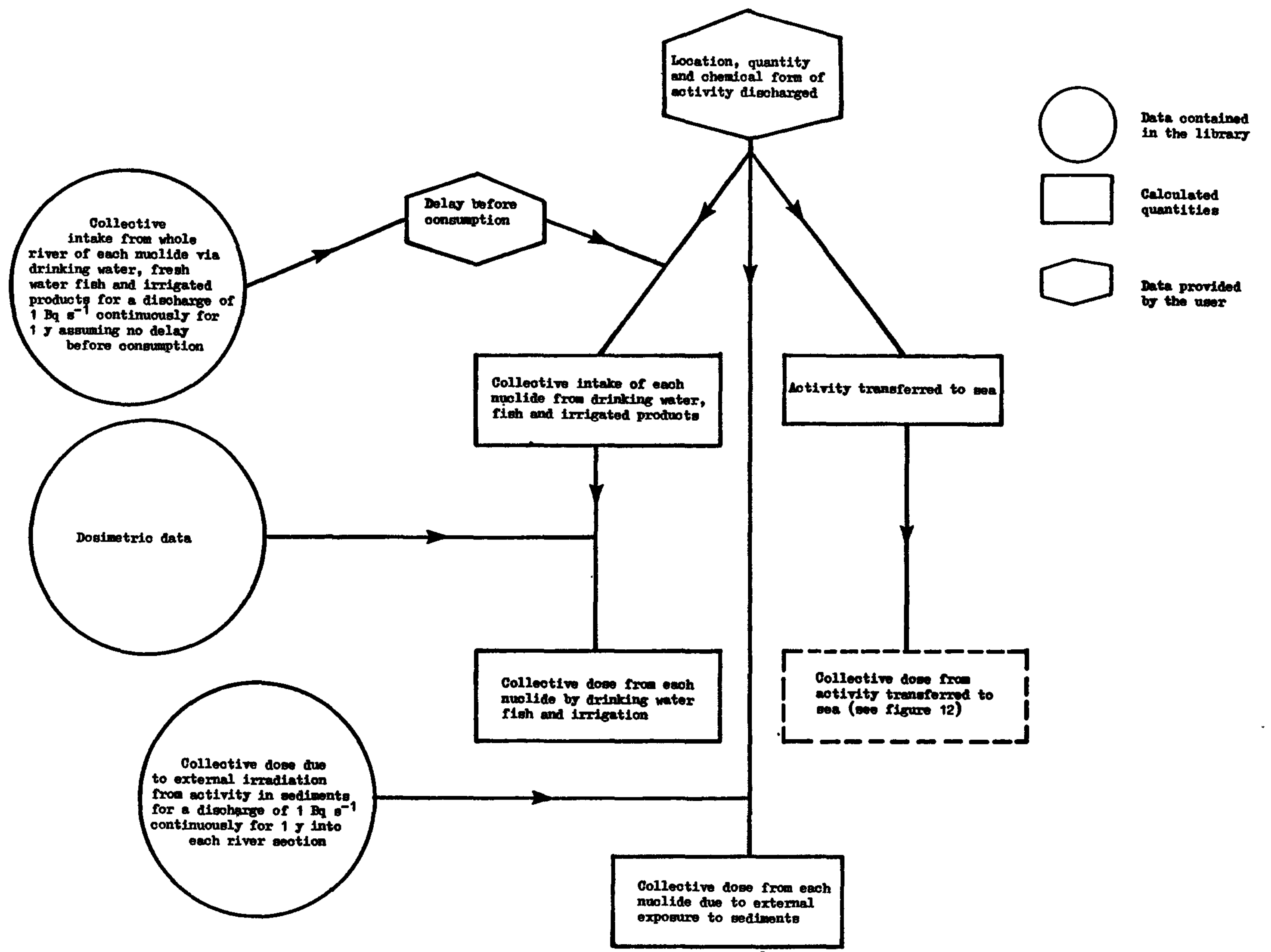


Figure 7. The scheme for calculating collective doses for discharges to a river

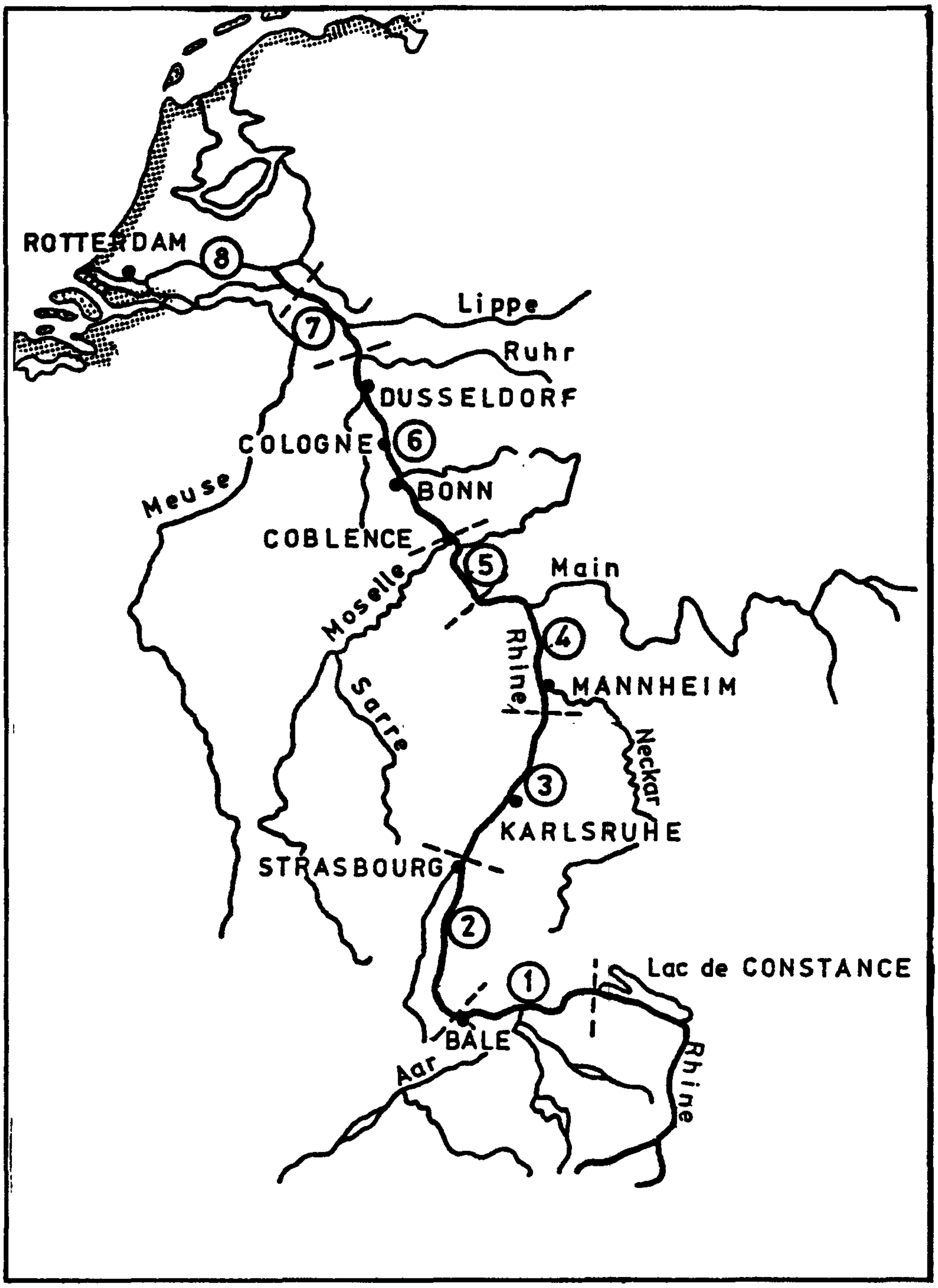


Figure 8. Sections of the Rhine

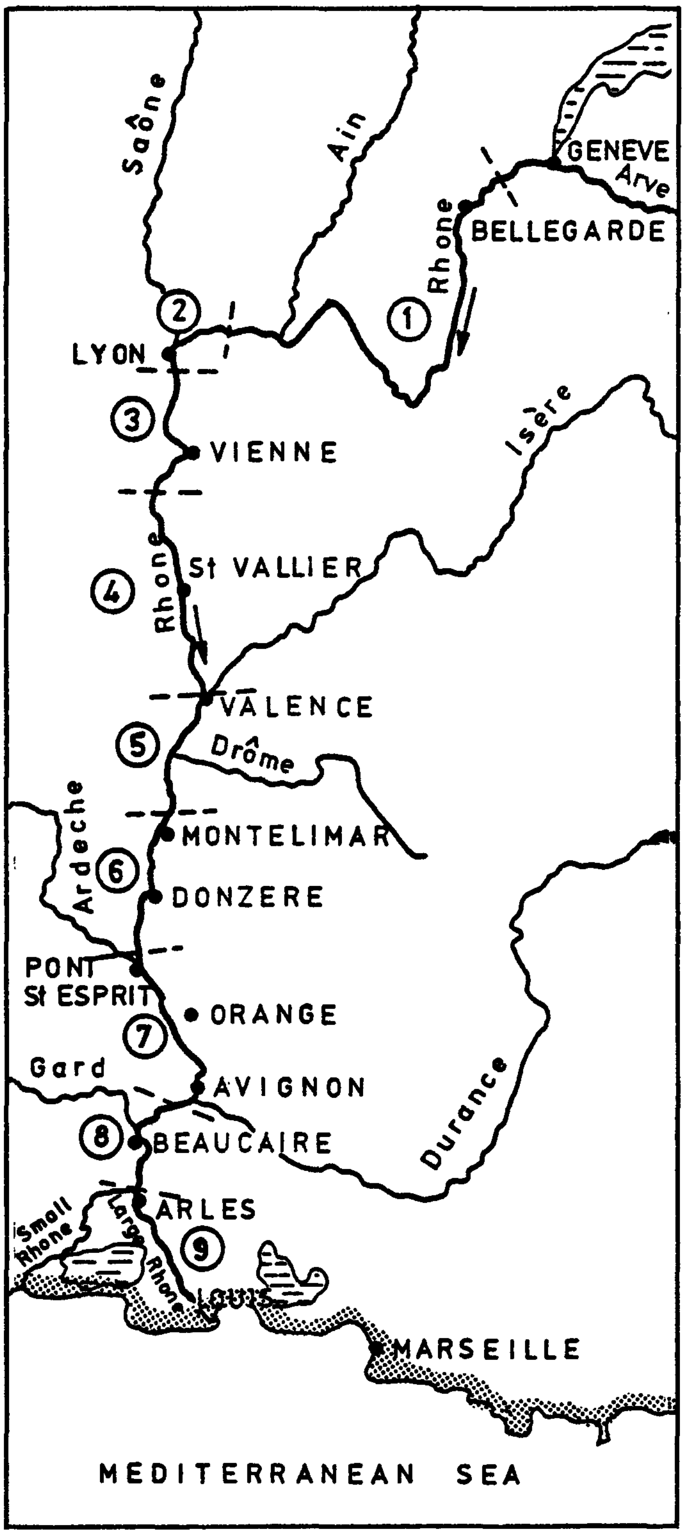


Figure 9. Sections of the Rhone

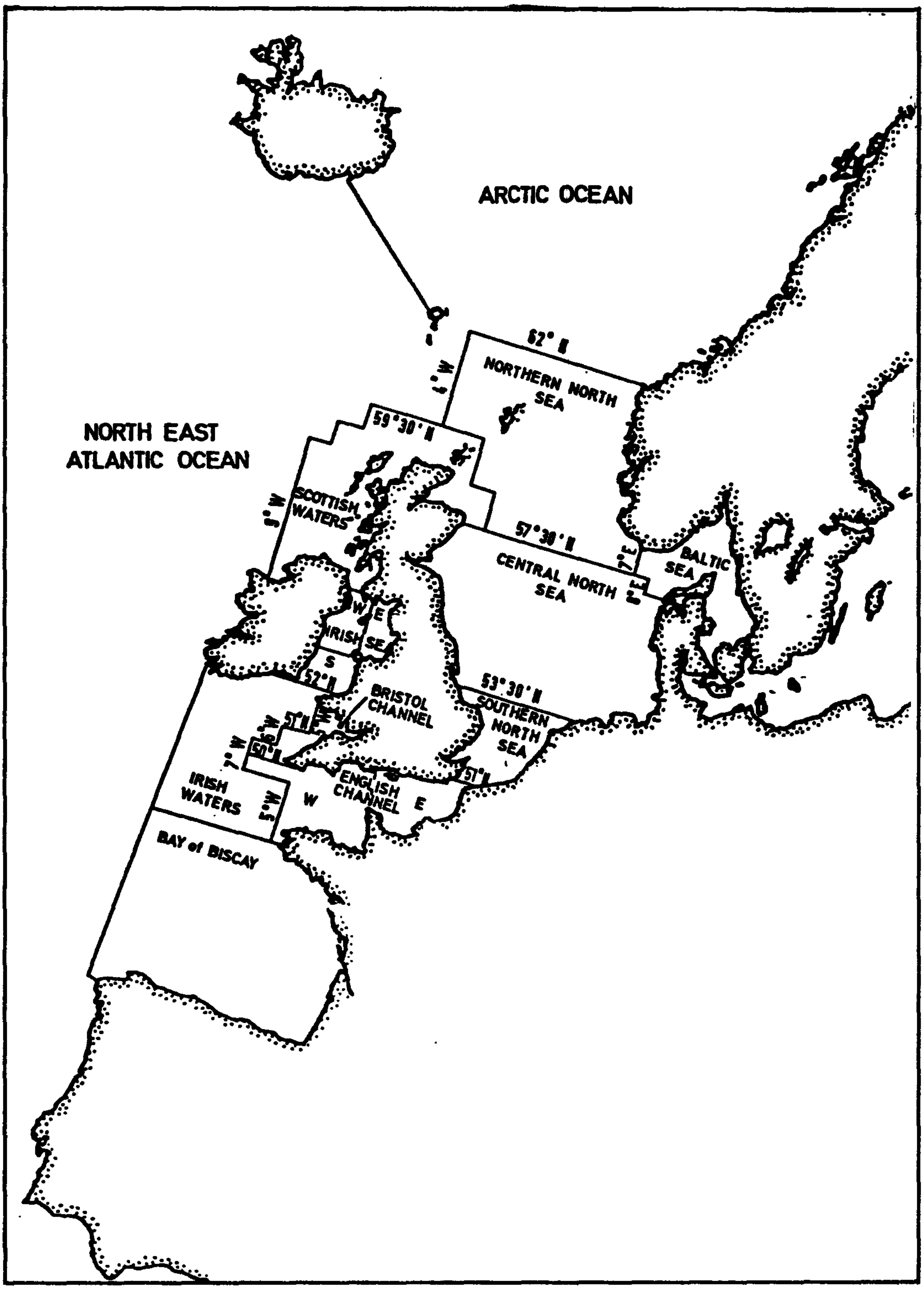


Figure 10. Compartment model of the Northern European waters

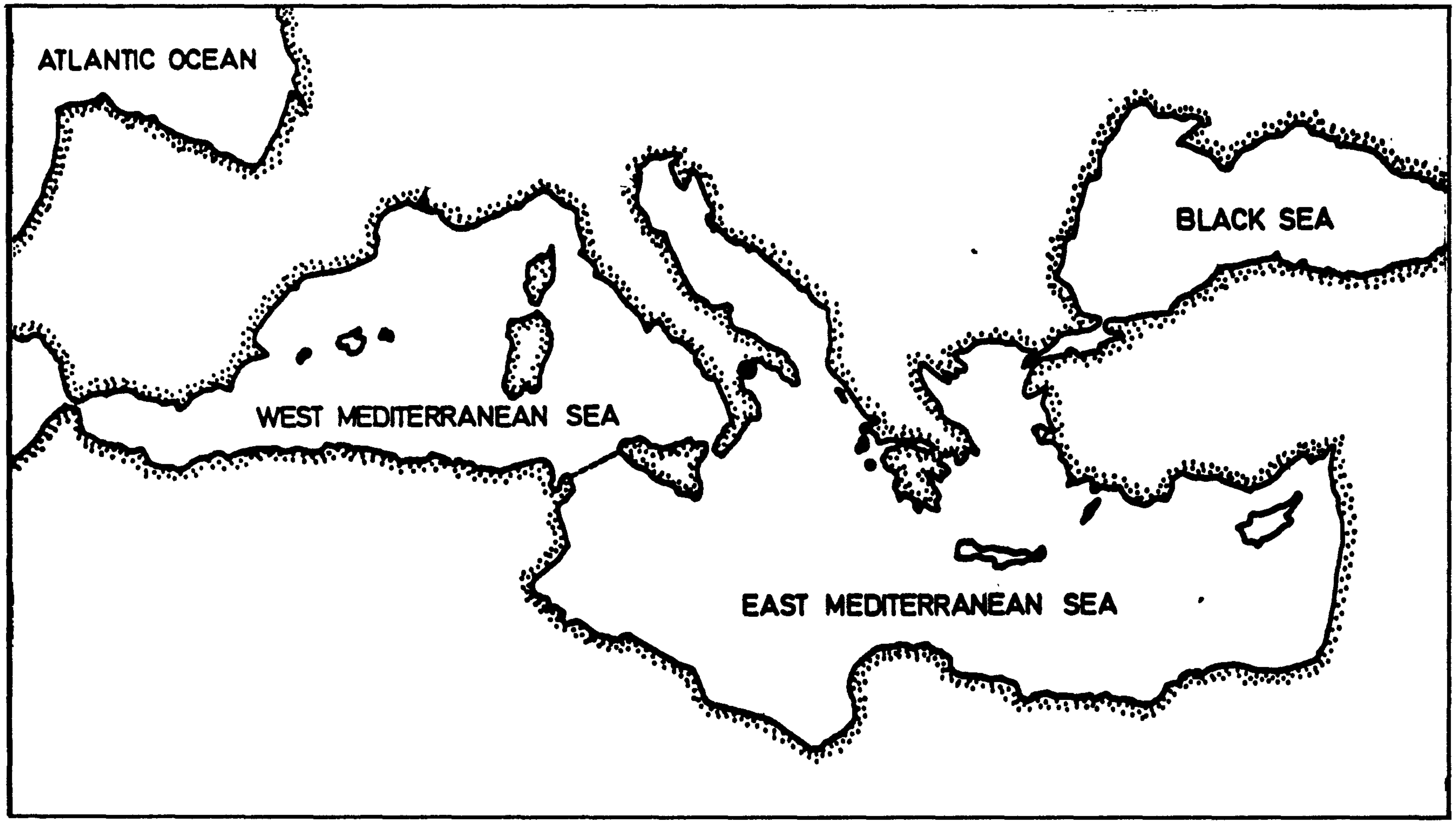


Figure 11. Compartment model of the Mediterranean sea

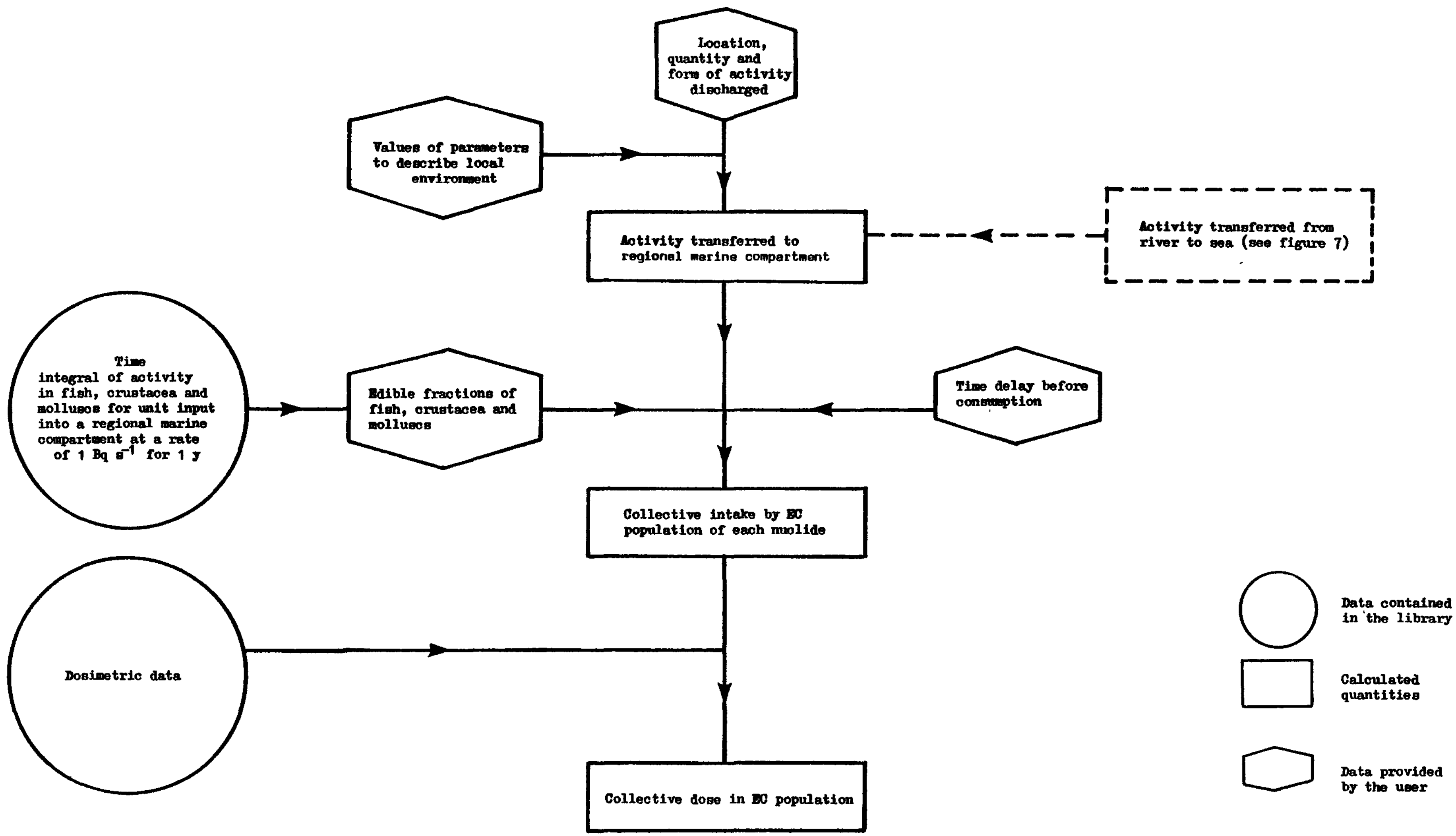


Figure 12. The scheme for calculating collective doses from marine discharges