POSEIDON VERSION 2.0 : APPLICATION TO A POTENTIAL RELEASE IN WEST CHANNEL ASSOCIATED WITH THE SEA TRANSPORTATION OF PLUTONIUM OXIDE

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SUMMARY

POSEIDON version 2.0 is a PC/Windows conversational computer code to assess the radiological consequences associated with a continuous or immediate release of radioactive material in the marine environment [Lepicard, Raffestin 1997]. Doses are calculated by considering the exposure pathways associated with the ingestion of marine foodstuffs, derived from specific data concerning concentration factors in sea products (fish, mollusc, crustacean and seaweed) and the corresponding average yearly consumption. The time scale for the evaluation of the consequences can range from medium to long-term. A specific module allows to estimate individual doses associated with various reference groups of population.

GENERAL DESCRIPTION

A box modelling approach has been adopted in POSEIDON computer code, to cover all European seawaters. The dispersion of radionuclides in the marine environment and the exposure pathways are based on the methodology developed within EC projects [European Commission 1990 and 1995]. In this approach, the dispersion processes for the radionuclides in the marine environment refer to mechanisms of transport by water exchanges between compartments and sediment scavenging. The sediment processes result from three phenomena : depletion of suspended materials in equilibrium with the water phase activity, diffusion of radioactivity between layers and bioturbation, modelled as a diffusive process on the boundary layer.

The major assumption inherent to any box modelling is the homogeneity of each compartment with respect to its parameters (i.e. suspended sediment load, sedimentation rate, depth), and an equal distribution of activity within the considered volume. Exchanges between compartments are expressed in terms of annual transferred volume of water. With respect to the radiological impact of some radionuclides generated by radioactive decay, calculations have been extended to daughter products of a selected decay chain, by replication of the compartments system (Figure 1). For each radionuclide, the concentration is evaluated in all the compartments, and the dose associated with the ingestion of contaminated marine products is integrated according to specific radionuclide parameters and marine products consumption.

Due to the intrinsic characteristics and limitations of the box modelling approach and due to the size of the considered sea compartments, this kind of modelisation is more adapted to medium and long term assessments, ranging from a few years to few thousands years after the release. Short term local assessments would call for the use of different hydrodynamic modelling.

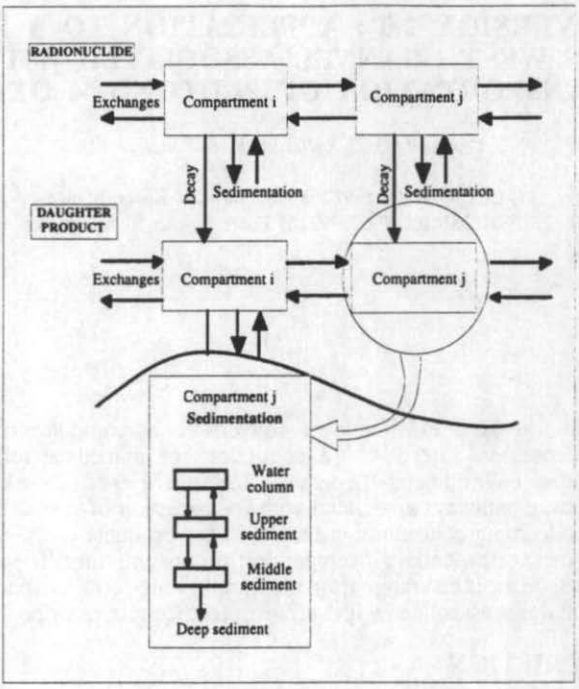

Figure 1: Modelling of the dispersion processes

CALCULATIONS AND OUTPUT

Once the release has been characterised (location and source term), the code simulates the dispersion of the radionuclides in the marine system. For each requested time period, concentrations of radionuclides in the filtered water (Bq/m^3 of filtered water) and in the first sediment layer (Bq/kg of dry sediment) are calculated in all compartments. Then, doses are evaluated on the basis of the edible fraction of the seafood which are ingested from each compartment (fish, shellfish, molluscs, and algae). For this purpose, the ingested activity is calculated, over each requested time period, according to the distribution coefficients (Kd) of the radionuclides in seafood. Collective doses per country are derived from these results and are presented for each radionuclide of the considered decay chain. Thereby, the relative influence of the decay products in the total collective dose can be appreciated. An average annual individual dose is calculated for all the time periods, corresponding to the annual collective dose divided by the population, assuming homogeneous geographical origins and consumption of seafood for the whole population of a country.

An additional module allows to estimate the individual dose received by specific groups of population. Such groups can be designed in POSEIDON version 2.0 by specifying the class of age, the individual yearly consumption of each type of sea product and their geographic origin (fishing location). A default set of reference groups is available in the database. As regards the origin compartment, it can be directly identified by its name or number, but the user can also ask the programme to scan, for each time period, all the compartments, to locate the one which leads to the highest exposure (conservative approach). The name/number of this so-called « most exposing compartment » is displayed to the user, as well as the results of individual dose calculations.

The results of concentration and dose calculations are displayed with tables and figures. They can either be directly printed or exported. Each run can be saved and further consulted.

IMPLEMENTATION

In the scope of the presentation of the capabilities of POSEIDON version 2.0, calculations have been carried out on the basis of an hypothetical accidental release of 1 kilogram of plutonium oxide (PuO_2) in the West Channel compartment, using the 44 compartment modelling of the European waters [European Commission 1995] (a close view of the North compartments is presented in Figure 2). By assumption, the release of the powder form oxide is supposed to be instantaneous (conservative approach). Five radionuclides from the inventory were retained for their relevant contribution to total doses, including the first daughter product of the Pu-241 decay chain (Am-241).

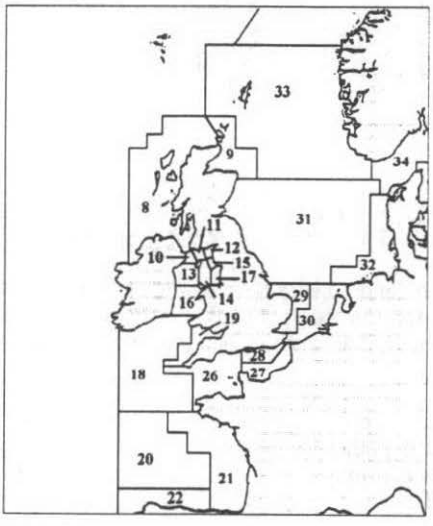

Figure 2: Detail of the North European compartments

Table 1: Characteristics of the source term instantaneous release of 1 kg PuO_2 in West Channel

Radionuclide	Committed effective dose[1] (Sv/Bq)			Activity (Bq/kg PuO_2)
	1 year	10 years	Adult	
Pu-238	$4.0\ 10^{-7}$	$2.4\ 10^{-7}$	$2.7\ 10^{-7}$	$1.0\ 10^{10}$
Pu-239	$4.2\ 10^{-7}$	$2.7\ 10^{-7}$	$2.5\ 10^{-7}$	$1.2\ 10^{12}$
Pu-240	$4.2\ 10^{-7}$	$2.7\ 10^{-7}$	$2.5\ 10^{-7}$	$1.8\ 10^{12}$
Pu-241	$5.7\ 10^{-9}$	$5.1\ 10^{-9}$	$4.8\ 10^{-9}$	$3.4\ 10^{14}$
Am-241	$3.7\ 10^{-7}$	$2.2\ 10^{-7}$	$2.0\ 10^{-7}$	$3.4\ 10^{12}$

(1) From ICRP 72

The cumulated collective doses integrated over 50 and 1000 years after the release are presented hereafter for Europe and France, derived from the yearly seafood consumption rate of those populations and the origin compartments.

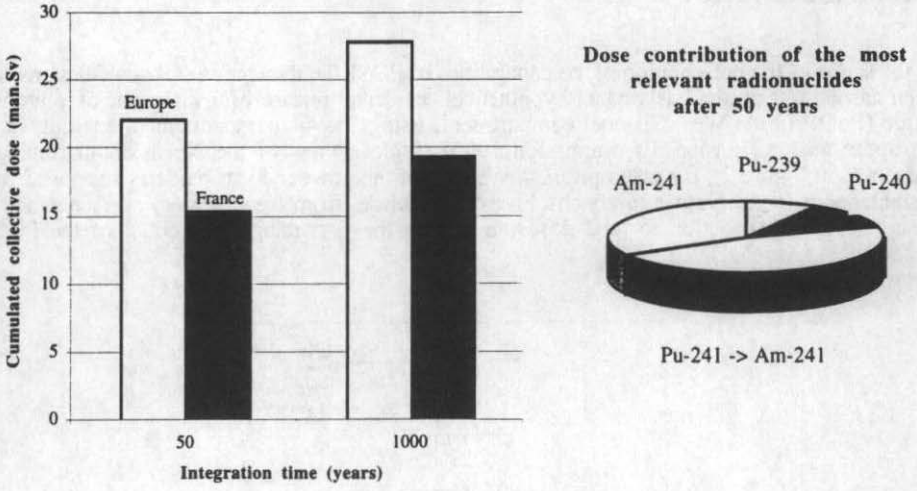

Figure 3: European and French collective doses associated with the release of 1 kg PuO_2 in West Channel

Assuming constant population and consumption rates, the collective dose integrated over 1000 years is about 28 man.Sv for Europe (population 350 millions) and 20 man.Sv for France (population 60 millions), noting that 90% of the collective dose is obtained within the 50 first years.

Using the individual dose module of POSEIDON version 2.0, annual individual doses have been appraised for different hypothetical reference population groups. A reference population group is characterised by its consumption of fish, crustaceans, molluscs and seaweed, and by the origin of these foodstuffs.

Table 2: Characteristics of the considered population groups

Reference group Individual consumption (kg/year)	Average European	Average French	IAEA 66 reference man [IAEA 1984]	French fisherman
Fish	10.5	8.4	110	15
Crustacean	0.5	4	36.5	5
Mollusc	2	4.6	36.5	5
Seaweed	0.1	0.4	36.5	0
Fishing compartment	All concerned compartments of the model	All concerned compartments of the model	English Channel West	English Channel West
Population of concern	Few 10 millions	Few 10 millions	Few people[a]	Few hundreds

[a] values selected to cover critical groups in all areas of the world according to current known dietary habits

The characteristics of the 'average European' and 'average French' groups have been established according to the seafood consumption rates of these populations, distributing their catches over all the European seawater compartments of the model. The dietary habits of the

'IAEA 66 reference man' have been considered to establish an hypothetical critical group made up of a few people catching their sea products in the release compartment West Channel. The 'French fisherman' population group has been set to be representative of a critical group collecting its seafood in the release compartment West Channel with consumption rates more coherent with the current known French fishermen dietary habits.

The estimated annual individual doses received by each group are presented in Figure 4 for the first year after the release. Given the release location and the characteristics of the reference groups, doses are supposed to be maximum during the first year after the release.

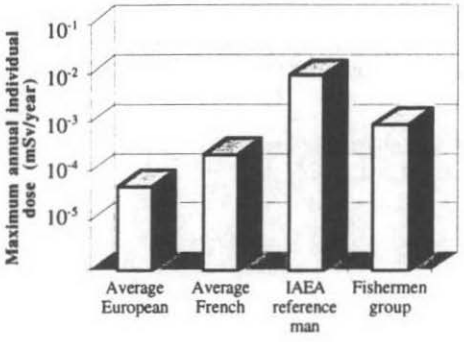

Figure 4: Annual individual doses estimated during the first year after the release of 1 kg PuO_2 in West Channel for four hypothetical reference groups

The individual doses estimated for the average European and average French reach 5 10^{-5} and 2 10^{-4} mSv respectively. The values corresponding to the 'French fisherman' and 'IAEA reference man' groups are about an order of magnitude higher, estimated to be 9 10^{-4} and 8 10^{-3} mSv respectively.

These estimations are rather explicit in showing how the definition of the reference group (consumption of seafood and fishing location) is essential in the calculation of individual doses, the results varying with few orders of magnitude from one reference group to another.

CONCLUSION

POSEIDON version 2.0 offers the possibility to assess the medium and long-term radiological consequences associated with continuous or accidental releases in the marine environment. Collective ingestion doses are appraised for the different countries of the model on the basis of the seafood provenance and the yearly consumption rates. An individual dose module allows to evaluate the individual doses received by specific population groups, such as people living near the coast for example. Depending on the release point, realistic population groups of sufficient size shall be characterised, according to their age, seafood consumption rates and fishing compartment. A conservative approach can be envisaged by requesting the code to systematically assign the 'most contaminated' fishing compartment to the considered population group.

REFERENCES

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