Low-Activation Reinforced Concrete Design Methodology (4)

- Classification System for Radioactive Waste Disposal –

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ABSTRACT

We have been developing the Low-Activation Reinforced Concrete Design Methodology (LARCDM) by using low-activation concrete to make waste disposal optimum condition. The main purpose of this work is to reduce the cost of radioactive waste disposal and enlarge region in nuclear facility whose activation is below clearance level. In this paper we report the system that evaluates the waste disposal classification and review the cost of waste disposal for the specified conditions (concrete).

INTRODUCTION

Radioactive waste which is generated from decommissioning activities or routine operations is, due to efficient disposal, classified into high level radioactive waste (HLW) and low level radioactive waste (LLW) in Japan. Furthermore, LLW is classified into three groups (Comparatively high radioactive level (L1), comparatively low radioactive level (L2), very low radioactive level (L3)) according to radionuclide inventory, and disposed in the Low-Level Radioactive Waste Disposal Center in Rokkasyo Mura, Aomori Pref., that is the only facility to have been licensed to dispose LLW. It is necessary to reduce the volume of radioactive waste because of following reasons. (1)The higher radioactive concentration is, the more expensive to dispose. (2)The amount of radioactive wastes to be disposed is limited due to the facility's capacity. (3)It is difficult to construct new facility because of an understanding of residents. And reducing the volume of radioactive waste contributes to the reduction of the impact on environment.

We have been developing low-activation design method for reduction of activated waste generated from Nuclear Facilities. This method is based on using low-activation concrete which contains Co, Eu lower than usual concrete.

LARCDM consists of development of low-activation concrete, radioactivity concentration map system for total nuclear facility life cost, and low-activation concrete development support system. In this report we will show radioactive concentration map (for disposal classification and cost estimation) system.

SYSTEM OVERVIEW

We can evaluate activated waste disposal classification, disposal cost and total life cycle cost with this system when we apply the low-activation concrete to an actual power station.

First, activation calculation of interested region where we intend to apply the low activation materials is curried out by using ORIGEN79 [1], ORIGEN2 [2] code, or simple calculation. Neutron flux and spectrum near reactor core for activation calculation have to be pre-calculated [3] by ANISN [4], etc. With this results, we can evaluate activated waste disposal classification, disposal cost and total life cycle cost. The outline of this system is shown in Fig.1. This system consists of activation calculation, decay calculation, radioactive concentration calculation, and disposal classification (Table1). Sample image of this system is shown in Fig. 2 and 3.

Table 1 Correspondence of calculation items and calculation programs

Calculation Item	Calculation Program	Executable file	Remarks
Activation	Geometry calculation	viewgeom.exe	Extraction of geometry data (from ANISN file)
	Activation calculation	Irradiation.exe	Produce cross section and activation calculation
Decay	Decay calculation	decay.exe	
Concentration	Concentration estimation	active.exe	
Classification	Classification waste	waste.exe	Calculation of summation of D/C Classification of radioactive waste disposal Evaluation of costs of waste disposal

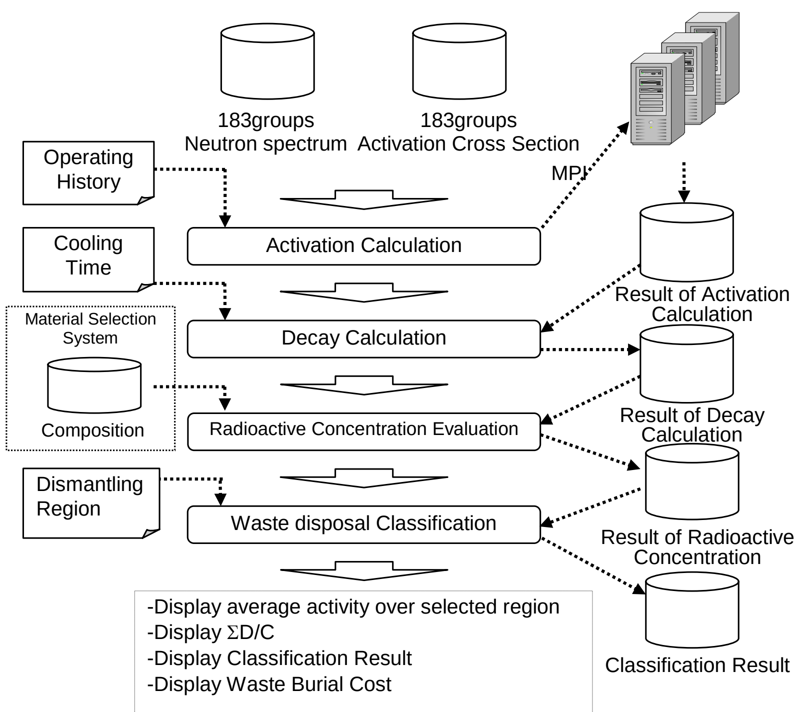

Fig.1 Diagram of the System

Fig.2 Setting of evaluation region of activation calculation (Sample)

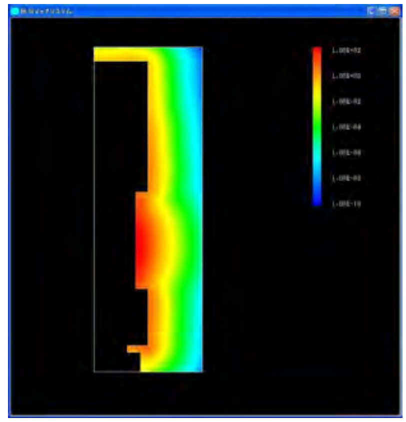

Fig.3 Two dimensional Induced activity distributions (Sample)

GEOMETRY SETTING PROGRAM

It is necessary to prepare neutron flux for this system because this system doesn't include neutron calculation performance. Geometry for activation calculation is extracted from the prepared neutron flux file or a data file. In one-dimensional ANISN calculation, since the configuration is not stored in the neutron flux file, it acquires from an input data. In ANISN, a geometry file is created from the number of meshes in the control data 15$ of an input data (IM), the number (IZM) of domains, the mesh boundary (4*), and the domain number (8$) and the material number (9$). On the other hand, in two-dimensional DORT, geometry data are added to the record of the head in a neutron angular flux tape, and using this, geometry files that common to one dimensional and two dimensional file are created. And the neutron flux file which have common file format in this system is created from each calculated neutron flux file.

ACTIVATION CALCULATION PROGRAM

This program carries out (1) extraction of 183-group neutron spectrum and flux, (2) production of 183-group activation cross section, (3) exchange of ORIGEN's original cross section for the 183-group cross section and (4) activation calculation. Activation calculation in this system is carried out by using ORIGEN2, ORIGEN79, or the simple formula which were included in this program.

a) Producing Cross section

In ORIGEN2 and a simple formula, activation cross section is composed by collapsing 183-group constants of JENDL3.3 into 1-group activation cross section data using prepared 183-group neutron spectra. And in ORGEN79, activation cross section data is composed from 183-group constants by collapsing into 3-group activation cross section data, whose energy range divided into fast neutrons (E>1.0MeV), medium neutrons (0.414eV<E<1.0MeV), and thermal neutrons (E<0.414eV). In case activation calculation is carried out with ORIGEN79, cross section library mentioned above and original library of ORIGEN79 are selectable. The new cross section library is exchanged to ORIGEN Original library.

b) Activation Calculation by ORIGEN2 and ORIGEN79

The induced activity calculation is practiced with input data for ORIGEN2 and ORIGEN79. Irradiation periods are modeled with operation duration from start-up to shut-down and gram-atom numbers are outputted as a file.

c) Activation Calculation by Simple Formula

Activation calculation in an analysis equation (simple formula) is as follows. In this case, it assumes that decay or reaction chain would be linear to make the calculation simple. Irradiation periods are modeled as duration from start-up to shut-down according to an operation history and gram-atom numbers are outputted as a file. Parameters for activation calculation are listed in table 2.

$$N_i(t) = N_i(0)\sum_{j=1}^{i} C_j \cdot \exp(-\Lambda_j t)\,, \tag{1}$$

$$C_j = 1 \qquad (i=1)\,, \tag{2}$$

$$C_j = \frac{\prod_{k=1}^{i-1}\Lambda_k}{\prod_{k=1}^{i}(\Lambda_k - \Lambda_j)} \qquad (i \ge 2,\ j \ne k) \tag{3}$$

where

$\Lambda_i = (\lambda_i + \sigma_i \phi)$ is modified decay constant;

$N_i(t)$ is number of atoms of nuclide X_i at time t after irradiation;

$N_i(0)$ is initial number of atoms of nuclide X_i;

λ_i is decay constant of nuclide X_i;

σ_i is activation cross section of nuclide X_i and

ϕ is neutron flux.

Table 2 Parameters of simple calculation

Nuclide	X_1 →	X_2 →	X_3 →	X_4
Number of atoms at time t after irradiation	$N_1(t)$	$N_2(t)$	$N_3(t)$	$N_4(t)$
Number of atoms at t=0	$N_1(0)$	$N_2(0)$	$N_3(0)$	$N_4(0)$
Decay Constant	λ_1	λ_2	λ_3	λ_4
Branching Ratio	$f_{1\to2}$	$f_{2\to3}$	$f_{3\to4}$	$f_{4\to5}$
Reaction cross section	σ_1	σ_2	σ_3	σ_4

DECAY CALCULATION PROGRAM

Induced activities at the timing of dismantling are calculated by using the result of induced activities after irradiation. Decay calculations are carried out by the Bateman equation as shown below and gram-atom number are outputted as a file. Here, nuclides in interest are the regulated nuclide for disposal and clearance regulation. Parameters of decay calculation are listed at table 2.

$$N_i(t) = N_i(0)\sum_{j=1}^{i} C_j \cdot \exp(-\lambda_j t) , \quad (4)$$

$$C_j = 1 \qquad (i = 1) , \quad (5)$$

$$C_j = \frac{\prod_{k=1}^{i-1} \lambda_k}{\prod_{k=1}^{i} (\lambda_k - \lambda_j)} \qquad (i \geq 2,\ j \neq k) \quad (6)$$

where,

Ni(t) is number of atoms of nuclide X_i at time t after irradiation;

Ni(0) is initial number of atoms of nuclide X_i;

λ_i is decay constant of nuclide X_i;

Table 3 Parameters of a decay calculation

Nuclide	X_1 →	X_2 →	X_3 →	X_4
Number of atoms at time t after irradiation	$N_1(t)$	$N_2(t)$	$N_3(t)$	$N_4(t)$
Number of atoms at t=0	$N_1(0)$	$N_2(0)$	$N_3(0)$	$N_4(0)$
Decay Constant	λ_1	λ_2	λ_3	λ_4
Branching Ratio	$f_{1\to2}$	$f_{2\to3}$	$f_{3\to4}$	$f_{4\to5}$

CONCENTRATION CALCULATION PROGRAM

The amount of activity of nuclide *i* is calculated by decay calculation for each element by multiplying the composition data of the material M from a material selection evaluation system [3]. The amount of activity of the nuclide for D/C calculation is saved at a file.

$$A_i = \sum_j (\mathrm{D}_{ij} \times \mathrm{W}_j) \times \lambda_i , \quad (7)$$

where

A_i is activity of X_i in material M;

D_{ij} is isotope ratio of nuclide *i* of element *j*;

W_j is weight of nuclide *j* in material M and

λ_i is decay constant of nuclide *i*.

WASTE DISPOSAL CLASSIFICATION PROGRAM

D/Cs for clearance examination and radioactive concentration for disposal classification are evaluated for the specified dismantling region by computing the amount of average activity of every mesh unit. Disposal classification in the specified region unit is determined from D/C and activity. The selection approach of the nuclide from regulated nuclide for D/C evaluation is shown in Fig. 4. Volume of the waste is estimated by dismantling area, and disopal cost is computed from the number of containers to be used, the rate of filling of a container and waste radioactive level.

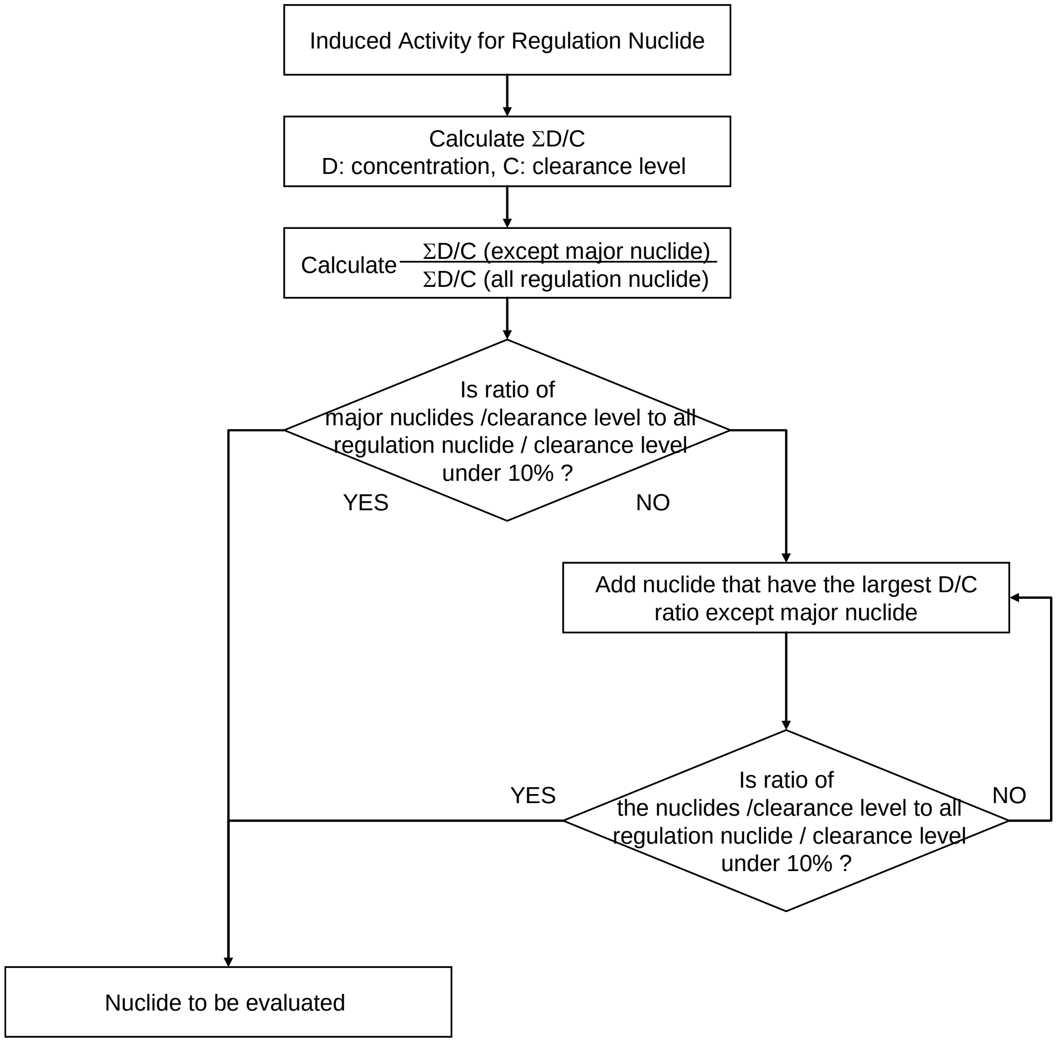

Fig. 4 selection of the object nuclide for clearance evaluation
Ref. AESJ Standard, Monitoring for Compliance with Clearance Level: 2005[5]

SYSYTEM FILE CONFIGURATION

Relation of each module and files in this system is shown in Fig. 5.

CONCLUSIONS

The system for radioactive waste disposal has been developed. This system can calculate the induced activity concentration to a nuclide ingredient, and can produce a classification level, disposal cost, etc. by using neutron flux prepared beforehand. For efficient LARCDM, we are going to unite this system with low-activation material development support system [6].

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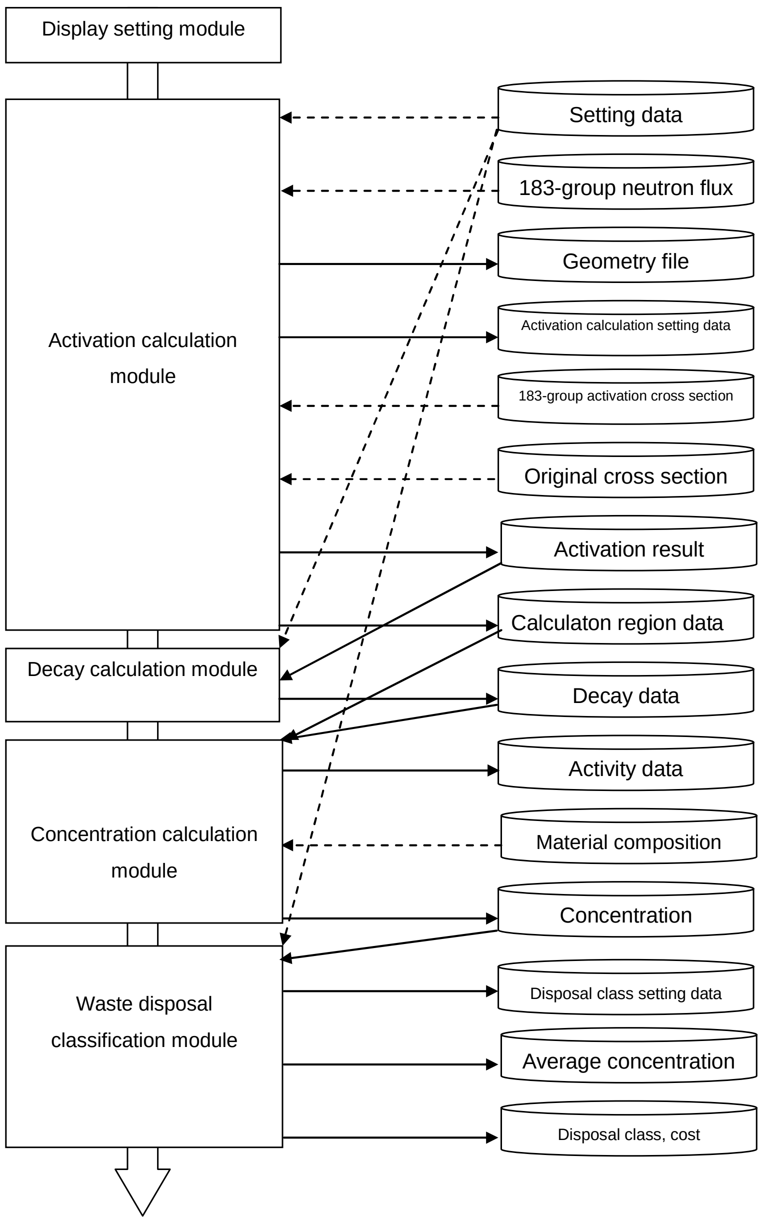

Fig. 5 Data flow in Calculation

NOMENCLATURE

D/C = radioactive concentration / clearance level.

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