

STUDIES ON TRITIATED WASTE MANAGEMENT SYSTEM

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ABSTRACT

Tritium is an isotope of hydrogen existing ubiquitously in the environment in the form of water. A treatment and disposal system considering the characteristics of tritium is proposed. The proposed system is composed of the three components of Waste Package, Repository, and Environment, (1) the Repository being an artificial, impervious tank having a spiral-shaped structure in (2) the Environment, and having the feature of being capable of controlling the migration path of groundwater,

INTRODUCTION

Tritium is a nuclide which has recently drawn attention in management of radioactive wastes. It is thought the amount of wastes containing tritium generated will increase in the future accompanying progress in research and development on nuclear fusion power generation by deuterium-tritium (D-T) reaction.

Radioactive wastes are sorted and managed in accordance with the properties of the waste itself, the character of the radioactive nuclide contained, its concentration level, or radiation level. Research and development is currently being carried out on those of such wastes that are of so-called low level, having low concentration and radiation levels based on the scenario of being disposed of at sea or on land after solidification. It is considered that more or less similar management will be possible fundamentally with regard to wastes containing tritium also.

This study concerns the proposal of a concrete system for taking tritium-containing wastes produced from nuclear fusion power generating systems based on D-T reaction, storing the wastes for a given length of time, providing the optimum treatment and disposal form for land disposal, and a method of evaluating the safety of the system. A conceptual drawing of the repository in the proposed system is shown in Figure 1,

BACKGROUND OF TRITIATED WASTE GENERATION

Definition of Tritiated Waste

Wastes contaminated by the fuel tritium, and wastes containing activated products originating from neutrons generated accompanying nuclear fusion reactions are produced from a nuclear fusion power generation system. To carry out management taking into account the characteristics of radioactive nuclides contained in the wastes, wastes mainly containing tritium and waste mainly containing other radioactive nuclides are to be separated and managed. Tritiated wastes are defined here as follows:

(1) Radioactive nuclides other than those of tritium are not contained as a result of separation by means such as distillation,

(2) Tritium is a chemical form of THO (water) which is an oxide form.

(3) In treatment of tritiated waste, it is to be solidified by a matrix to impart immobility and sealed in a container.

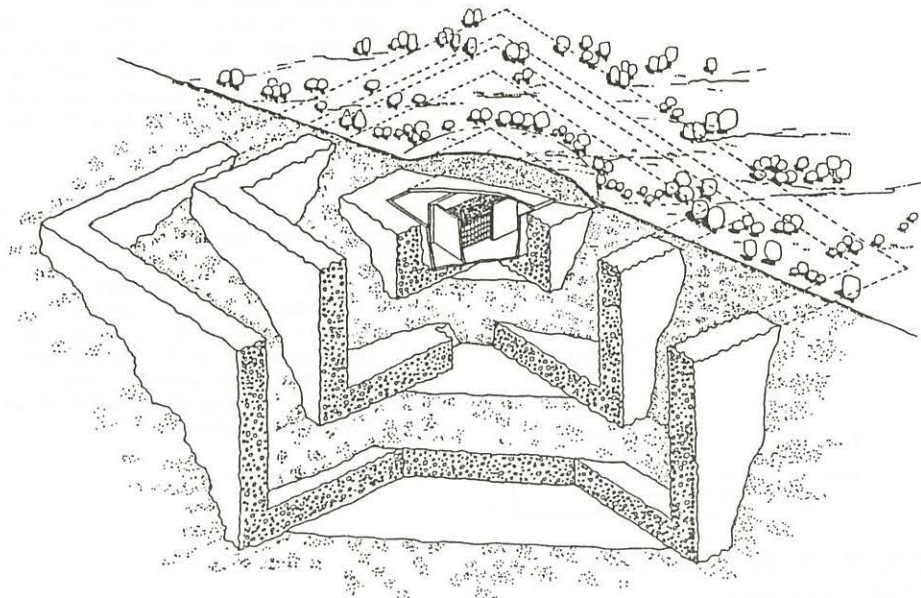


FIGURE 1: CONCEPTUAL DESIGN FOR THE TRITIATED WASTE REPOSITORY

Characteristics of Tritiated Waste

Hydrogen, which is an isotope of tritium, assumes extremely varied chemical forms such as hydrogen gas, metal hydrides, hydrocarbons, and oxides, the phases of which existing at normal temperature are gas, liquid, and solid.

Because of this, if the chemical form of tritium contained in waste were to differ, properties which present problems in management will differ. When tritium is in gaseous form, the fact that it is a gas at normal temperature, explosiveness, and great diffusibility are the problems. As an oxide, that is, even in the form of water, the facts that there is considerable vapor pressure, that isotope separation from waste liquid which is of large quantity and is diluted is difficult, and that it moves through ground strata of the environment at the same velocity as water are problematic. In carrying out disposal, it will be necessary to eliminate this ease of movement. In effect, it is necessary to make the tritium immobile.

On the other hand, since the half-life of tritium is 12 years, the period during which isolation is necessary will be of the order of 10^2 years. This period, when the integrity of the barrier making up the disposal system is considered, may be said to be something which can be coped with using the present level of technology. Furthermore, it may be said that there is little biological influence since only β rays of weak energy are emitted as a result of decay.

Flow of Treatment and Disposal

With regard to treatment and disposal of tritiated wastes, the flow as a whole from generation in a D-T fusion system to migration into the environment is shown in Figure 2. Figure 3 shows the management procedure at the time of generation.

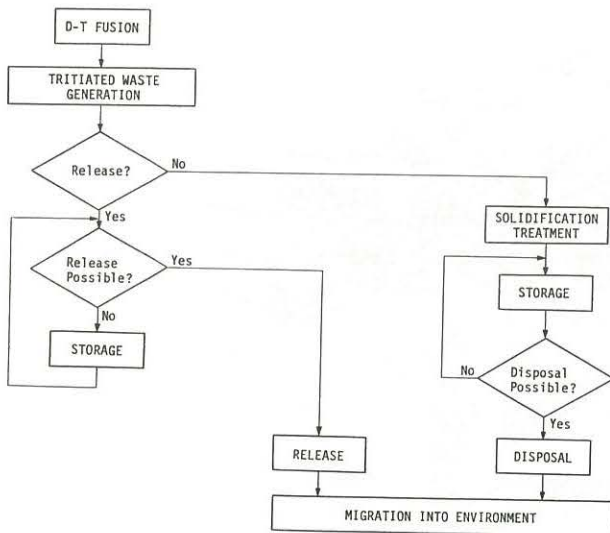


FIGURE 2: CONCEPT OF TREATMENT AND DISPOSAL OF TRITIATED WASTE

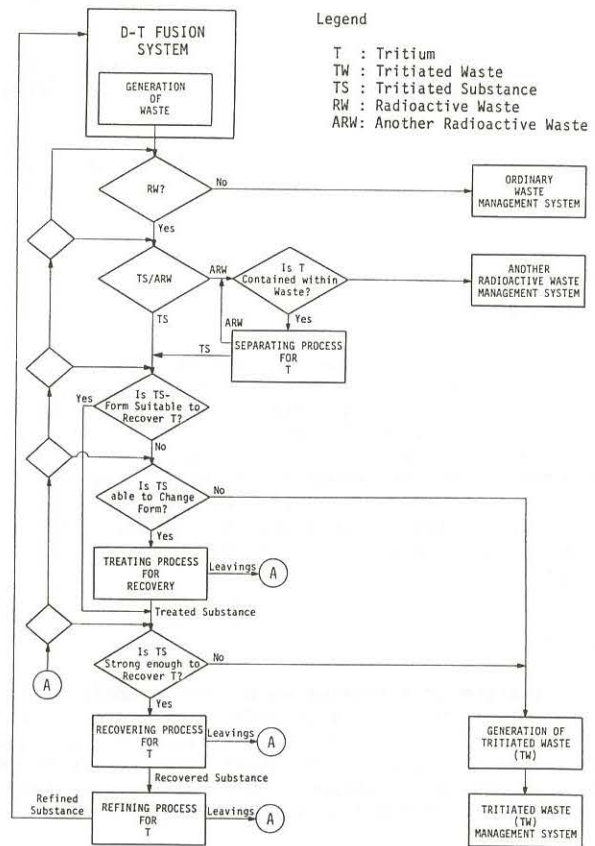


FIGURE 3: GENERATION OF TRITIATED WASTE

It may be considered that various kinds of wastes will be produced from a nuclear fusion power generation system, and firstly, radioactive wastes and other wastes in general are sorted apart and separation is made from other radioactive nuclides. For this purpose, it is necessary for the classification level to be distinctly laid out. Next, it is studied whether the form of the tritiated substance separated is suitable for recovery of tritium, or whether it can be changed into a form where recovery is possible. Tritium is regained from substances from which recovery is possible, and is refined, with the residue returned to the treatment steps.

Material deemed unrecoverable upon being put through these steps is left to the waste management system as being non-reusable. The quantity and concentration of the waste at that time will greatly affect the load on the management system. If the recovery efficiency is high, and as a result the tritium concentration of the waste is low, it will be possible for the waste to be discharged, and if of small quantity, management such as storing the material, awaiting decay during the period of storage, and then releasing can be done.

DEFINITION OF TRITIATED WASTE MANAGEMENT

The authors' conception of tritiated waste management in the proposed system is summarized in Table 1. A centralized disposal system is adopted in the scenario for low-level radioactive waste management presently being considered. In the event this system is adopted, the scale of a single disposal facility will be large. There will also be the need for transportation from the generating facility to the disposal facility.

TABLE 1: CONCEPT OF TRITIATED WASTE MANAGEMENT

Subject	Item	Detail	Selection
Management Scenario	Concentrated disposal		
	Self-concluding disposal		○
Treatment	Chemical form of TW ^a	THO	○
	Treatment form	Solidification (200 l drum)	○
Disposal System	Land disposal	Shallow-ground type	○
	Sea disposal	Dumping	
Quantification of TW ^a	1,000 pkg/yr	1 GWe class	○

a. Tritiated waste.

With the nuclear fusion power generation system now under development, the form wherein manufacture of tritium other than that initially charged is done at the same facility is the most likely to be adopted and a management scenario of self-concluding type including stages up to disposal is conceivable. Hereafter, in this study, disposal of self-concluding type will be considered.

The treatment system is to be for THO which is a chemical form of water and solidification is to be done in a container. With regard to the matrix for solidification, the system of fixation by hydration reaction of cement and other inorganic materials is promising.

Other treatment systems are the following:

(1) Tritium in the chemical form of T₂ or TH is made to be absorbed by metal for fixation in the form of a metal hydride.

(2) Tritium is fixed in the form of hydrogen or hydroxyl group in an organic material.

It may be said that both of these systems are unsuitable for treating large quantities of dilute waste liquid.

Disposal systems conceivable are sea disposal by dumping and land disposal by burial. Although sea

disposal is a promising method because of the great isolating capacity and diluting capacity of the sea, the possibility of land disposal of tritiated wastes expected to increase in the future was examined. This was because in consideration of the characteristics of tritiated wastes that the period of isolation required is of the order of 10² years, while the biological effects are small, it was thought to take up shallow-ground disposal in subsequent studies.

Finn calculated on a trial basis the amount of tritiated wastes expected to be generated from a commercial Tokamak type fusion power generation system of 1 GWe class to be 0.52- 0.74 TBq/day (14- 20 Ci/day) [1]. The authors assumed three levels of the quantity of tritium contained in wastes and obtained the number of solidified units varying the concentrations at the time of solidification. The condition at that time was that 100 l of waste would be put in one 200-l drum can. The results are given in Table 2. The amount of tritium wasted is 0.5 to 0.7 g/yr according to Finn's trial calculations, which is close to the case in the table of 1 g/yr.

TABLE 2: RELATION OF TRITIATED WASTE GENERATED AND NUMBER OF SOLIDIFIED UNITS PRODUCED

Tritiated Waste Generated (g/yr)	T Concentration in Treated Water (MBq/l)	Water Treated (l)	Number of Solidified Units ^a (pkg/yr)	T Concentration of Solidified Units (GBq/ton)
10	360,000	1,000	10	90,000
	36,000	10,000	100	9,000
	3,600	100,000	1,000	900
	360	1,000,000	10,000	90
1	36,000	1,000	10	9,000
	3,600	10,000	100	900
	360	100,000	1,000	90
	36	1,000,000	10,000	9
0.1	3,600	1,000	10	900
	360	10,000	100	90
	36	100,000	1,000	9
	3.6	1,000,000	10,000	0.9

a. The increase in volume due to solidification is twofold and the drum can capacity 200 l/can. In effect, the quantity of treated water possible to solidify in one drum is 100 l.

b. The density of the solidified material is considered as 2.0 kg/l.

In the study described below, capacities of repository facilities were obtained with the number of solidified units produced per power generating facility as 1000 unit/yr.

METHOD OF SAFETY EVALUATION

Securing of safety in a treatment and disposal system for radioactive wastes ultimately means to reduce the effect of radiation due to radioactive nuclides circulated to the sphere of human livelihood through migration to the environment, and controlling this within a range that can be ignored for practical purposes. To evaluate such safety, it was decided to resolve the problem in stages by the procedure indicated below.

- (1) Arrangement of structuring components, and further, of subcomponents of the system.
- (2) Evolvement of function of each subcomponent. This reveals the main and subordinate functions of each subcomponent through matrix evolvement.
- (3) Evolvement of performance of each subcomponent. This consists of determining the performance values required for each subcomponent to fulfill its functional role.
- (4) Preparation of event tree and fault tree and quantitative evaluation of effects. Predicated on probabilistic approach by FTA
- (5) Comprehensive evaluation of environmental safety

It was considered as follows regarding the components making up the system and the functions that they should have. With respect to the components the thinking of IAEA was referred to, and the three components below were considered [2].

- (1) Waste Package
- (2) Repository
- (3) Environment

The following were considered regarding functions that the three components should possess so that the components would serve as multiple barriers to migration of tritium into the Environment:

- (1) Waste Package
 - . Immobility, or the property of not easily flowing
 - . Spatial isolation, or the state of being confined in a container and separated from others.
 - . Retardation effect, on physical and chemical change, especially the effect of retarding leaching of tritium
 - . Water cut-off or hindering of movement of water with regard to action of water from outside
 - . Ease of handling from engineering standpoint
- (2) Repository
 - . Protection of Waste Package against human external forces such as destruction by war, mining, etc.
 - . Protection of Waste Package against natural external forces such as earthquake, volcanic activity, crustal movement, etc.
 - . Retardation of groundwater movement
 - . Retardation of movement of tritium leached from Waste Package
 - . Possession of thermal diffusibility against heat generation of the Waste Package
- (3) Environment
 - . Limitation of groundwater paths in surroundings of Repository
 - . Reduction in concentration of leached tritium
 - . Protection of Waste Package and Repository
 - . Partial transpiration into atmosphere of leached tritium

With regard to this report, as described in the following chapter, evolvement of the individual subcomponents is done concerning the concrete system proposed

to clarify what functions the components of the system should possess.

PROPOSAL OF CONCRETE SYSTEM

A system based on shallow-ground land disposal, the concept of which is shown in Figure 1, is proposed for treatment and disposal of tritiated wastes.

The contents and functions of the three components of the system are described below.

Waste Package

The following are considered as subcomponents of the Waste Package:

- (1) Waste form, solidified unit
- (2) Container and/or coating. Container with coating as necessary
- (3) Absorber material
- (4) Protective sleeve and/or coating. Protective sleeve with coating as necessary

Table 3 is a matrix showing the relations of subcomponents and functions. The o marks indicate functions that subcomponents should mainly have, and Δ marks functions that can additionally be expected. It

TABLE 3: MATRIX OF SUBCOMPONENTS AND FUNCTIONS OF WASTE PACKAGE

Subcomponent Function	Waste Form	Container (& Coating)	Absorber Material	Protective Sleeve (& Coating)
Securing of Immobility	○	Δ		
Securing of Spatial Isolation	Δ	○		○
Securing of Retardation Effect	Δ	○	○	○
Protection against Water from Outside	Δ	○	Δ	○
Protection against Mechanical External Forces	Δ	○	Δ	○
Securing of Engineering Operability	○	○	Δ	

Note. ○ shows indispensable function, and Δ shows adjunctive function.

can be comprehended that all functions can be fulfilled with solidified units and containers. The adoption of absorber material and protective sleeves needs to be studied from the standpoint of multiple protection.

Repository

The following are considered as subcomponents of the Repository:

- (1) Backfill material
- (2) Wall and/or lining. Structural members such as walls, floors, ceilings, etc. with linings provided as necessary
- (3) First artificial water barrier
- (4) Fill and vegetation

The structure including walls was arranged from inside to outside in spiral form as shown in Figure 4.

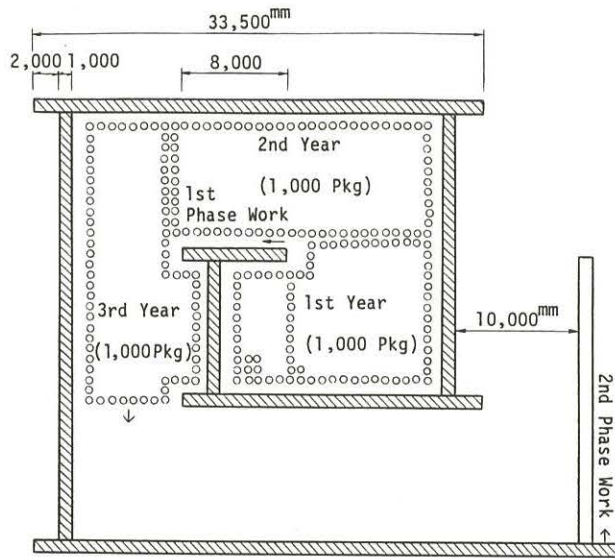


FIGURE 4: CONCEPTUAL DRAWING OF PLANE OF PROPOSED SYSTEM

The following features are obtained from this arrangement:

- . Expansion can be done adjusting the accommodating capacity in accordance with the quantity of waste generated.
- . In principle, if the wall at the outermost periphery is kept sound at all times, the safety of the entire system can be secured.
- . In an emergency, it will be possible for a wall to be built still farther outside.
- . By applying slurry wall techniques, it is possible to construct safe and sure shallow-ground facilities.

At the periphery of the structure, a first artificial water barrier is provided by a soil stabilization method to increase the retardation effect against groundwater movement. Accordingly, it becomes possible for this to be applied to diverse ground conditions.

The relations of the four subcomponents making up the Repository are shown in Table 4, and it may be comprehended that all functions can be fulfilled with the structure including backfill material and walls,

TABLE 4: MATRIX OF SUBCOMPONENTS AND FUNCTIONS OF REPOSITORY

Subcomponent Function	Backfill	Wall (& Lining)	1st Artificial Water Barrier	Embankment & Vegetation
Protection against Human External Forces	△	○		△
Protection against Natural External Forces	△	○		
Retardation of Groudwater Movement	△	○	○	○
Retardation of Tritium Migration	○	△		
Securing of Thermal Diffusibility	○	△		

Note. ○ shows indispensable function, and △ shows adjunctive function.

Environment

The subcomponents making up the Environment are as follows:

- (1) First dilution zone/second artificial water barrier and vegetation
- (2) Second dilution zone/third artificial water barrier and vegetation
- (3) Ground strata around Repository
- (4) Exclusion area

Outside of the first artificial water barrier is defined as the Environment, where first and second dilution zones demarcated by second and third artificial water barriers are provided. In this way, by working on a part of the Environment, it was made possible for the concentration of tritium leached out from Waste Packages and the Repository to be reduced, and the groundwater movement path limited.

The groundwater movement paths when dilution zones have been provided are shown in Figure 5, and groundwater seeping down from the ground surface at the Repository always flows from the center of the facility toward the outer fringe, Diffusion and dilution of tritium goes on during this time.

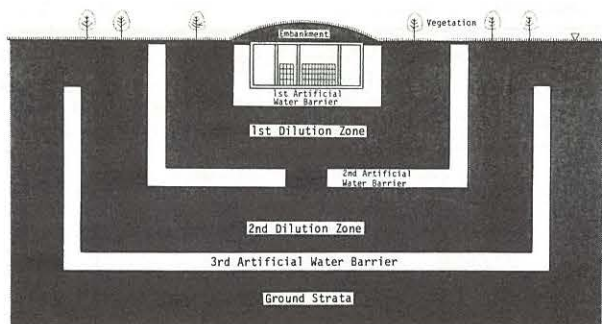


FIGURE 5: CONCEPTUAL DRAWING OF CROSS SECTION OF PROPOSED SYSTEM

The relations of the subcomponents making up the Environment and the functions fulfilled are shown in Table 5,

TABLE 5: MATRIX OF SUBCOMPONENTS AND FUNCTIONS OF ENVIRONMENT

Subcomponent	1st Dilution Zone/ 2nd Artificial Water Barrier & Vegetation	2nd Dilution Zone/ 3rd Artificial Water Barrier & Vegetation	Ground Strata Surrounding Repository	Exclusion Area of Ground Surface
Function				
Limitation of groundwater path	○	○	△	△
Reduction of concentration	○	△	△	
Protection of waste package and repository				○
Patial transpiration		○	△	

Note. ○ shows indispensable function, and △ shows adjunctive function.

CONCLUSION

The results obtained up to this time in the joint research, "Disposal of Radioactive Wastes Containing Tritium and an Evaluation Model on the Disposal Form" commenced in 1984 by Nagoya University and Mitsui Construction Co., Ltd, have been summarized.

Performance evolvement of the various subcomponents accompanied by demonstrations through experiments is presently being done according to the procedure described under the chapter "Proposal of Concrete System," and by making safety evaluations based on the data it is intended to make the proposed system one that is of even more concrete form. The authors would

be gratified if their work were to be of some value in bringing about a full-fledged nuclear fusion power generation age.

REFERENCES

- (1) FINN, P. A., "Commercial Tokamak Reactor", ANL/FPP/TM-125, 1979.
- (2) IAEA, "Criteria for Underground Disposal of Solid Radioactive Wastes", STI/PUB/612, Vienna, 1983, Chapter 3.