Evaluation of Permeable and Non-Permeable Tritium in Normal Condition in a Fusion Reactor

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Abstract. The tritium cycle, technologies of process and control of the tritium in the plant will constitute a fraction of the environmental impact of the first generation of DT fusion reactors. The efforts of conceptual development of the tritium cycle are centered in the Internal Regenerator Cycle. The tritium could be recovered from a flow of He gas, or directly from solid breeder. The limits of transfers to the atmosphere are assumed ~ 1 gr-T/a (~20 Ci/a) (without species distinction). In the case of ITER, for example, we have global demands of control of 5 orders of magnitude have been demonstrated at experimental level. The transfer limits determine the key parameters in tritium Cycle (HT, HTO, as dominant, and T₂, T₂O as marginal). Presently, the transfer from the cycle to the environment is assumed through the exchange system of the power plant (primary to secondary). That transport is due to the permeation through HT, T₂, or leakage to the coolant in the primary system. It is key the chemical optimization in the primary system, that needs to be reanalyzed in terms of radiological impact both for permeable, HT, T₂, and non-permeable HTO, T₂O. It is necessary considered the pathway of tritium from the reactor to the atmosphere, these processes are modelled adequately. Results of the assessments were early and chronic doses which have been evaluated for the Most Exposed Individual at particular distance bands from the release point. The impact evaluations will be performed with the computational tools (NORMTRI), besides national regulatory models, internationally accepted computer these code for dosimetric evaluations of tritiated effluents in operational conditions.

1. Introduction
The two common forms of tritium contribute in a different way to the Effective Dose Equivalent (EDE). Both chemical forms, HT and HTO, have a different behaviour in the environment. The elementary tritium from the emission point converts to HTO by microbiological agents near the soil surface. When it is deposited in the ground it suffers the transformation rapidly to HTO (less than one week). This process is only influenced by the dry deposition, because the rain intensity factor does not influence the incorporation from the elementary tritium. On the other hand, HTO chemical form is influenced by the dry and wet deposition. The atmospheric and geometric conditions are a decisive factor in the contribution levels from the tritium to the dose. All calculations were carried out reproducing a real approach, considering distances from 100 m to 100 km from the emission point and a population density of 100 persons/km² in rural and urban scenarios.
NORMTRI code [1] uses a statistical Gaussian model to estimate air and ground contamination for quasi-stationary releases. This also includes HTO re-emission from both soil and vegetation. HT and HTO releases are treated separately. The specific tritium content (HTO) in vegetation water is originating from tritium in soil and atmosphere [2, 3]. The relative humidity determines which tritium fraction must be taken from the atmosphere or soil [4]. Tritium concentration in the organic material (OBT) is assumed to be in equilibrium with tritium in plant water [5, 6]. These doses are the addition of those for internal irradiation by ingestion, internal irradiation by inhalation of the primary plume, internal irradiation by absorption to the skin and inhalation by re-emission at the atmosphere.

2. Transfer from primary to the atmosphere

The development of Tritium Cycle for DEMO fusion reactors (see Figure 1) is in first stages on its conceptual design. The first criteria is to minimize the environmental impact of systems processing very large amounts of tritium, using strong requirements in terms of control, in special at the normal operations. These control demands are already demonstrated at experimental level in ranges of process of ITER.

![Figure 1. Cycle of Tritium (HCLL/DEMO). ISS (Isotope Separation System), TRS (Tritium Recovery System from He), TES (Tritium Extraction System, FW (First Wall), SG (Steam Generator), CPS (Coolant Purification System), HCS (Helium Cooling System), RC (Recirculator), WDS (Water Detritiation System).](image)

The tritium economy of fusion technology should be bred at rates higher than the consumption ones, for this reason, the tritium source input term in Inner Breeding Cycle results the contribution of tritium bred in breeding material plus tritium coming from DT plasma implantation at the First Wall.

Transfer limits determine key parameters of the Tritium Cycle is the acceptable limits of different tritiated species in the primary coolant. The transfers from Internal Regenerator Cycle of Tritium to the environment are assumed in its group as transfers primary/secondary (assumed as atmosphere) through the systems of recovery of power. Transfers are due to permeation of species HT and T₂ or for leakage of coolant primary (all existent species).

3. Dose evaluation to the environment

In DEMO design, the limits of transfers to the atmosphere are assumed to be ~ 1 gram of Tritium (HT or HTO) per year for normal operation. The maximum values are in the near ranges of the reactor, about 100–400 m away from the emission source for any forms of tritium. All those calculations were made for 10 m and 30 m of stack, see Figure 2.

In routine operations, the contribution to the total dose by inhalation and skin absorption depend on the boundary conditions. If the release of tritium (in HTO form) to the atmosphere is 10 m above the ground, the contributed to the total doses is one order of magnitude higher than for the same release at...
30 m of height. But in the case of HT, the different heights of the stack is only important close to the emission (<1 km).

![Dose vs. point emission distance](image)

Figure 2. Dose vs. point emission distance (for 10m and 30m stack). The doses are measured by EDE during one natural year.

The maximum total dose, in both cases, is observed at short distance from the emission point. The contribution of elementary tritium in routine emissions from the initial plume to the internal dose by inhalation is negligible. But in the case of the HTO, the dose by inhalation is higher than HT [7, 8]. In contrast, the doses by re-emission are higher for the HT release; for this reason the HTO maintenance in the atmosphere near the surface (from HT to HTO conversion) is continuous.

The ground deposition increases the final doses of water tritium, since it is incorporated to the ground, surface waters, underground waters, and in finally, to the food chain of plants and animals.

4. Conclusions

The tritium equivalent and effective doses are different according to the distance away from the emission point for both chemical forms, but in any case are higher than 1 mSv [9]. The difference of doses in HT and HTO emission is due to the contribution to total doses by re-emission, it is important at short distance but not at large distance, because 95% of the HT deposited on the surface is returned to the air as HTO, increasing the atmospheric levels to HTO. The inhalation doses of the primary plume can contribute up to 20-30% of the total dose, and only the HTO has a significant contribution.
For the first re-emission to the atmosphere, the elementary tritium has larger importance than the HTO, shown in Table I.

Table 1. Total dose percentage of different contaminated pathways at near distance from the emission point at 10 m of height. IH%: inhalation and skin absorption, IG%: ingestion, IHR%: re-emission.

| DISTANCE (M) | IH% | IG% | IHR% |
|--------------|-----|-----|------|
| 145          | 0.14(27.78) | 94.87(71.01) | 4.99(1.21) |

Therefore, the permeable tritium form has its larger contribution in the cases of ingestion and re-emission to the atmosphere, while the HTO is important for inhalation processes and internal tritium ingestion. At near distances from the reactor the doses reach a maximum value for any chemical form, which changes according to the height of the emission. The reason can be found in the contribution ingestion, that can even be up to 80-98% of the total dose; this effect being larger at short distances in routine emissions and strongly depend of the height of the emission.

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