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Comparison of the Tritium permeated from ITER Blanket in normal operation and its short range impact of HT over France, Swiss or Spain

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Summary – In this paper we consider hydrogen isotope (HT) permeation from a liquid metal (LM) ITER breeder blanket (assuming normal operation and a LM as DCLL or HCLL blanket) as a possible source of a tritium leak or release, as the main,, but not the only, source. The paper presents modeling of short-range low-impact HT gas activity over France, Swiss or Spain after release from ITER for sample 2014 and 2015 local weather conditions. The permeation of hydrogen isotopes is an important experimental issue that needs to be taken into account for the development of a Tritium Breeder Module for ITER [1]. Tritium cannot be confined - without an uncertainty of 5% in the flux permeation - and therefore HT can be detected (e.g. by ionization chambers) as it permeates though the structure of RAFM steel towards the coolant [1]. HT arising from Pb15.7Li, and permeated through Eurofer97, can contaminate other parts of the system and may be transported though the normal-vent detritiation system (NVDS). Real-time forecasts of the transport of tritium in air from the fusion reactor towards off-site far-downwind locations though extended tritium clouds into low levels of the atmosphere is calculated for the short range (up to 24 hours) by the coupling of 2 models the European Centre for Medium Range Weather Forecast (ECMWF) [2] model and the FLEXPART lagrangian dispersion model [3] verified with NORMTRI simulation [4] and implemented in many different cases and scenarios [5, 6, 7]. As a function of daily weather conditions, a release may affect just France or it may move towards Switzerland, under cyclonic circulation, or towards the Iberian Peninsula or Balearic Islands (Spain) when a HIGH produces anticyclonic circulation of air over the Mediterranean Sea.

1. HYDROGEN ISOTOPES PERMEATION

The permeation of hydrogen isotopes is an important experimental issue in the development of a Tritium Breeder Module for ITER, the fuel-tritium –as of today experimentally cannot be 100% confined - permeates though the structure of RAFM steel to the coolant (figure 1), from where it can contaminate the other parts of the system and can be delivered though the normal-vent detritiation system (N-VDS). Within the tritium plant of ITER a total inventory of about 2–3 kg will be necessary to operate the machine

in the DT phase. During plasma operation, tritium will be distributed in the different sub-systems of the fuel cycle. [1].

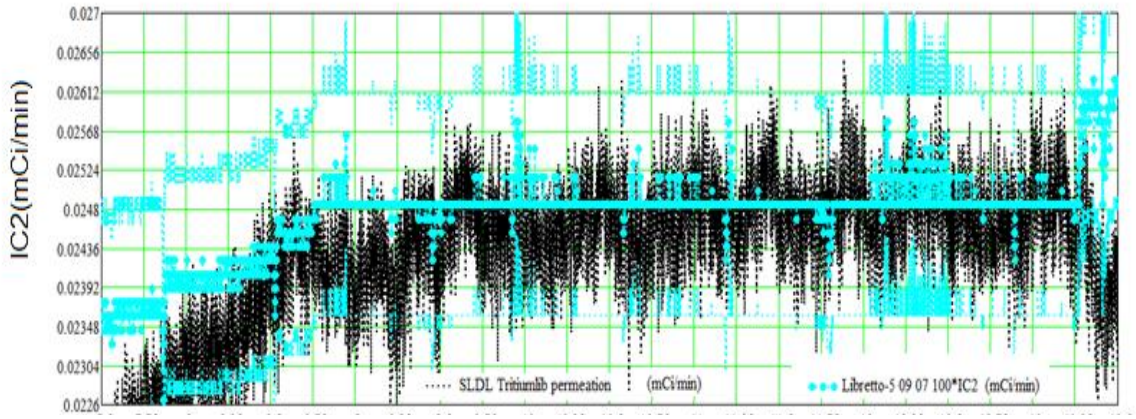

Figure 1 Permeation of tritium in EUROFER detected in the ionization chamber 2 of HFR Petten (blue dots).

In this paper we assume an *exaggerated source term* of "1 kg of elemental gas of HT". This assumption allows for a better simulation of the effects of HT bigger forecast release over the Mediterranean Area. (In principle this release may be due "normal" operation condition. On the other hand to calculate the real time forecast of transport of tritium in air from off-site the fusion reactor towards far downwind (even more than 100 km) though extended tritium clouds into the atmosphere [6]. It is calculated for the short range (up to 24 hours) by the coupling of 2 models the ECMWF weather forecast model and the FLEXPART lagrangian dispersion model verified with NORMTRI and implemented in many different cases and scenarios. We evaluate a short range impact of HT activity over France, Swiss or Spain from 2 cases in 2014 and 2015 for cyclonic and anticyclonic circulations in line with the previous assessments [5].

2. SHORT RANGE IMPACT OF HT GAS OVER FRANCE AND SPAIN IN CASE OF AZORES HIGH PRESSURE SYSTEM DISPLACED TOWARDS THE WEST MEDITERRANEAN

Concerning the level, our main interest is the HT cloud at the level of 60 m (HT3) due configuration of ITER release (from 4 stacks of 60 m) (In addition we already compute the levels of 10m and 30m in order to have a comparison of maxima elemental gas concentration close to ground or mean sea level pressure). Concerning the area, our main interest is the inland areas selected for France, Spain and Swiss[6]. With both boundary conditions (in the vertical and in the area of interest) the trajectory of level 3 is the one that can be followed and the results are in the figures 2 and 3.

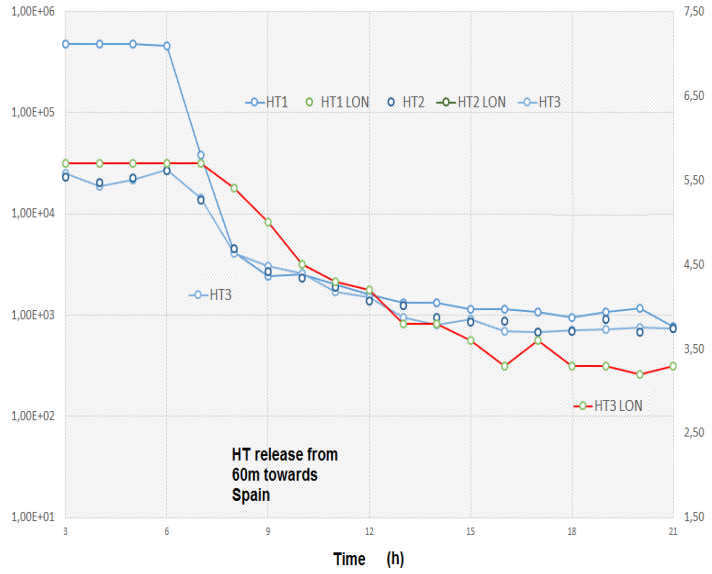

Figure 2. ECMWF/FLEXPART forecast dispersion of HT close to France after 3 hours with values of HT3 release toward Spain under 100 KBqm-3 until 12 hours, then values under 10 to 1 Bqm-3 until 21 hours.

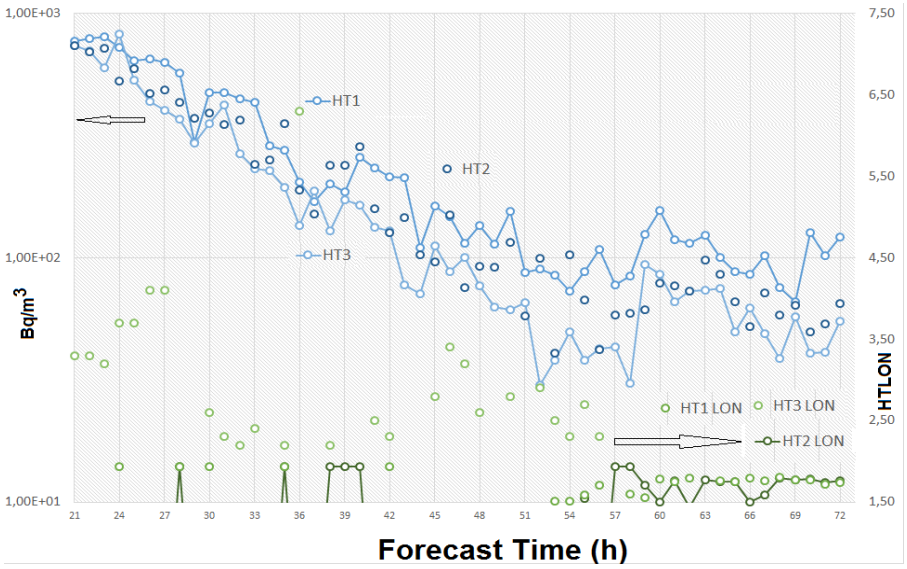

Figure 3. Output ECMWF/FLEXPART forecast dispersion of HT close to Spain after 21 hours with values under KBqm^{-3} until 45 hours, then values under 100 Bqm^{-3} until 72 hours.

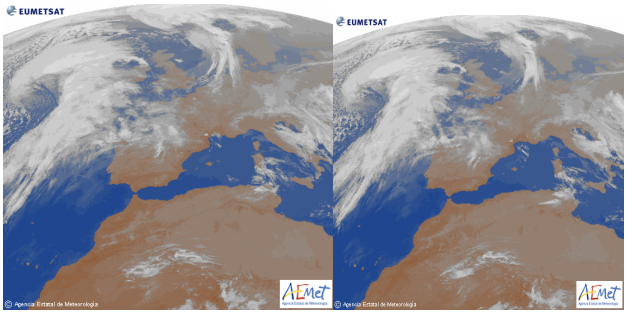

Figure 4. Thermal IR satellite images from 11 March 22 and 23 UTC presents the stagnant air mass (under high pressure conditions). Sources EUMETSAT and AEMET

Figure 2 represents ECMWF/FLEXPART forecast dispersion of HT close to France after 3 hours with values of HT3 release toward Spain under 100 KBqm^{-3} until 12 hours, then values under 10 to 1 Bqm^{-3} until 18 hours. The figure 3 presents the ECMWF/FLEXPART forecast dispersion of elemental tritium gas – may be mainly but not only from tritium permeated in ITER and N-VDS effluents without a perfect clean- when arrive close to Spain after 18 hours with values under KBqm^{-3} until 45 hours, then values under 100 Bqm^{-3} until 72 hours. The High Pressure conditions over Spain (and France) are presented on the Eumetsat –from an thermal infrared (IR) channel- satellite images corresponding to the day 11th of March 2015, as presented in the images of figure 4 at 22 and 23 UTC.

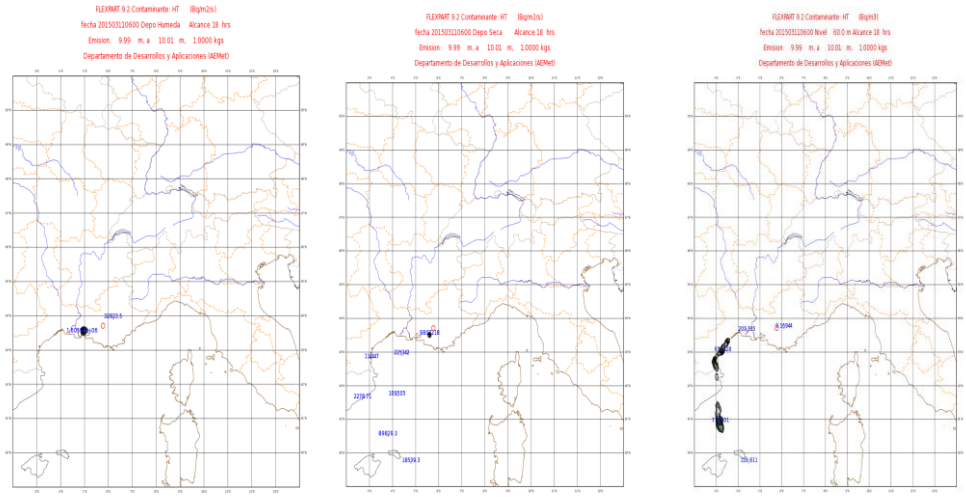

Figure 5. HT3 FLEXPART forecast of contaminations derived on Spain at 18 hours

Figure 5 shows the situation over Spain with the cloud of HT3 (at 60 m) in 11 of March 2015. In addition to situation at the French area is represented by Flexpart model; forecast HT at 60 m (hereafter HT3, as the other levels should have corresponding concentrations of elemental gas HT as HT1 and HT2 at 10 and 30 m). *The figure include first products of approaches to HTDD dry and HTWD wet depositions*.

3. SHORT RANGE IMPACT OF HT OVER FRANCE AND SWISS IN OTHER CYCLONIC CIRCULATION.

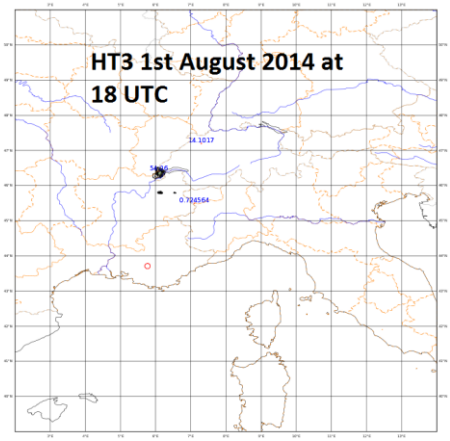

Figure 5. HT3 situation of low over France at ecmwf- flexpart forecast 18 hours corresponding to 1st August 2014

The study case of a low corresponds to the 1st August 2014 and the figure 5 presents exclusively the FLEXPART products at T+18 HT3. In the table 2 the HT1, and HT2 are already included. The HT cloud has arrived to Leman Lake (Swiss).

4. COMPARISON OF CONCENTRATIONS OF HT

Table 1. Maximum HT in High weather conditions 11 March 2015

HT	***Date/Hour***	***HT (Bqm^{-3}) Over France High conditions. Initial contamination***	***Date/Hour***	***HT (Bqm^{-3}) Over Spain High conditions derived contaminations***
HT 10 m	*11/03/15 at 3.00 UTC*	*455017*	*11/03/15 at 18.00 UTC*	*944*
HT 30 m	*11/03/15 at 3.00 UTC*	*22925*	*11/03/15 at 18.00 UTC*	*686*
HT 60 m	*11/03/15 at 3.00 UTC*	*18597*	*11/03/15 at 18.00 UTC*	*710*

Table 2. Maximum HT in Low conditions 1st August 2014

HT	***Date/Hour***	***HT (Bqm^{-3}) Over France Low conditions initial contamination***	***Date/Hour***	***HT (Bqm^{-3}) Over Swiss Low conditions derived contaminations***
HT 10 m	*01/08/14 at 3.00 UTC*	446787	*01/08/14 at 18.00 UTC*	*57*
HT 30 m	*01/08/14 at 3.00 UTC*	8227	*01/08/14 at 18.00 UTC*	*53*
HT 60 m	*01/08/14 at 3.00 UTC*	8600	*01/08/14 at 18.00 UTC*	*54*

In table 1 the derived contamination of elemental gas HT arriving Spain in 18 hours is under 1 KBqm^{-3} (low or cyclone weather conditions) and therefore should be not a problem in all cases. HT3 is just 710 Bqm^{-3}. In table 2 the derived contamination of elemental gas HT arriving Swiss in 18 hours is under 1 KBqm^{-3} and therefore should be not a problem in all cases. HT3 is just 54 Bqm^{-3}. This is one order of magnitude lower than in anticyclone conditions. At 18 UTC the concentrations arriving to Spain or Swiss seems to be not significant enough to study dose or to establish and emergency system. However the concentrations of elemental gas in derived contaminations, are 1 order of magnitude major in case of high or anticyclone weather conditions, than in case of low of cyclonic weather conditions. In this examples Spain (figure 5) should be *more contaminated* than Swiss (figure 6).

5. THANKSGIVINGS

The authors wish to thank AEMET for supporting the ECMWF and Flexpart software requirements in this paper. FLEXPART headers are maintained in the figures presented in order to clarify dates and forecast times. Eumetsat images are taken from the AEMET Web page as a Member State of the Meteosat operational exploitation agency.

6. CONCLUSIONS

The Transport of HT from Cadarache (France) in the initial conditions (at source) and as derived contamination (far from source) is predicted for both High and Low pressure conditions.

In both cases, higher concentrations of the elemental gas HT occur over Cadarache where FLEXPART graphical produces “little clouds at H+3”, meaning high or very high concentrations. The concentrations of elemental gas in derived contaminations are at least 1 order of magnitude greater in the case of high or anticyclonic weather conditions when compared to the case of low or cyclonic weather conditions.

It is considered that further studies should be done for neighboring countries or regions, such as Italy and the islands of Corsica, Sicily, and Sardinia as well as the Balearic Islands. This should be done in case contaminations over Mediterranean atmosphere were the object of study. Furthermore, it should be considered that maritime vessels can contribute to the imbibitions of pollutants by clouds (including HT from Cadarache).

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