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POTENTIAL RADIOACTIVE LIQUID DISCHARGE PROGRAM IN DANUBE BLACK SEA CANAL BY CERNAVODĂ NUCLEAR POWER PLANT IN 2009

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Abstract. During the maintenance works performed between 22^{nd} October and 9^{th} November 2009 at the Cernavoda Nuclear Power Plant, the entire volume of cooling water of both units, estimated to 250 m^3, was discharged into Danube-Black Sea Channel. Entire process was carefully monitored by measuring the volume of discharged water as well as its Tritium content. For a better monitoring, the Tritium activity concentration was measured not only in the vicinity of Cernavoda NPP but also about 64 km downstream, at the Galesu - Palas water treatment facility plant.

Throughout this period, the maximum values of Tritium activity concentrations in the Danube-Black Sea Channel never exceeded 28 Bq/l, significantly lower then the maximum allowed values for non-occupational exposure of 100 Bq/l. More details concerning the estimated as well as experimentally measured Tritium content are presented and discussed.

Key words: Nuclear power plant; Tritium; Radioactive discharge; Release criteria.

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1. INTRODUCTION

The Cernavoda Nuclear Power Plant (NPP), comprising two 700 MW CANDU units, is located in the Dobrudja area, four km far away of the city of Cernavodă, in the proximate vicinity of both Danube River and Danube-Black Sea Channel. Regarding the last one, it is worth mentioning that it represents the main sources of cooling water for NPP reactors, and, at the same time, the places where the cooling water could be discharged.

The Danube-Black Sea Canal with a length of 64.4 km is situated between the Port of Constanta South-Agigea (Southern Branch) and Navodari (Northern Branch) and the Danube River, the near city of Cernavodă (Fig. 1). Three locks: one at Cernavodă and the other two at Navodari and Agigea assure a constant level of water

Fig. 1 – A schematic map of the Danube-Black Sea Channel. Blue stars show the location of Cernavodă NPP as well as of the Galesu-Palas water treatment plant collecting points.

at a depth of 7.5 m. Along its entire length, the Channel has a width of 90 m, reaching 90 meters in the curvature areas. In the vicinity of the Poata Alba village, the main channel splits into Northen Branch (Poarta Alba - Navodari) and Southern Branch (Poarta Alba - Agigea). Its average debt attends a maximum around 23 m^3/s in the summer time, decreasing to m^3/s in winter. The mean water speed varies between 0.01 m/s and 0.047 m/s. There are no tributaries in the area, except cooling water discharge from NPP, kept constant by the two existing locks. For this reason, the water discharges from the plant represent the largest contributor to the water flow in the Channel.

As Cernavodă NPP use CANDU technology, Tritium represents the main radioactive pollutant prone to be released into environment by liquid and gaseous effluents, mainly as tritiated heavy water [1, 2]. During the routine exploitation of the Cernavodă NPP, the radioactive liquid wastes resulting from plant operations, including the cooling water, are collected in five 50 m^3 hold-up tanks. Periodically, in the course of maintenance operation, their content is discharged in a controlled mode into Danube River or Danube - Black Sea Channel, provided that a minimum dilution factor of 2900 is ensured during this operation. To check that the emission of both gaseous and liquid radioactive effluents are below regulatory limits, the specific activity of Tritium as well as the overall alpha and beta activity are continuously monitored. This compulsory procedure is of extreme importance as the the Danube -

Black Sea Channel is a source of drinking water and land irrigation.

Accordingly, between 22^{nd} October and 9^{th} November 2009, as as result of maintenance procedures, the entire volume of cooling water of both units of Cernavodă NPP were directed to Danube-Black Sea Channel through the Condenser Cooling Water Duct (CCWD). This process was carefully monitored by measuring the volume of discharged water and Tritium content at the exit of CCWD as well as about 64 km downstream, at the Galesu - Palas water treatment plant located on the Poarta Alba - Navodari branch (Fig. 1).

The results of this monitoring program will be further presented in this paper.

2. OPERATION PLAN TO REDUCE AQUEOUS WASTE WITH HIGH CONTENT OF RADIOACTIVE TRITIUM AND THE LIQUID DISCHARGE

In order to ensure an adequate control of the radioactive discharge into CCWD, the following steps are scheduled: i. - prior to pump-out of the contents of a tank to the CCWD, the contents of the tank should be recirculated to ensure good mixing, and a subsequent grab sample should be sent to the Chemistry Laboratory for radiometric analysis; ii. - based on the Laboratory analysis, the estimated annual Derived Emission Limits (DEL) for the actual pump-out are submitted to the Shift Supervisor for review.

The Shift Supervisor could authorize pump-out an individual tank only if it contains less than 0.5 % of the annual DEL for both gamma activity and Tritium content and provided that the total monthly estimated, (*i.e.* including the previous pump-out operations), is less than 3 % of the annually DEL. Otherwise, an approval of the Station Health Physicist is required.

Once the approval done, the pump-out operation could be initiated.

In normal, routinely conditions, the cooling water is pumped into the Danube-Black Sea Channel by means of three Condenser Cooling Water (CCW) and two Raw Service Water (RSW) pumps with a nominal flow of 11.5 and respectively 2.61 m^3/s. In the same conditions, the flow of radioactive liquid effluents discharge is of 200 l/min, value representing the nominal flow for a proper function of the Liquid Effluents Monitor.

To estimate the maximum concentration of Tritium in discharged liquid effluents as well as the maximum amount of Tritium in drinking water, we have used the following dilution factors F_d:

$$F_d = \frac{Cooling\ Factor\ Discharge\ [\mathrm{m^3/h}]}{Radioactive\ Waste\ Discharge\ Flow\ [\mathrm{m^3/h}]} \quad (1)$$

In these conditions, the radioactive effluent dilution factor in cooling water F_d showed to be equal to 13,650.

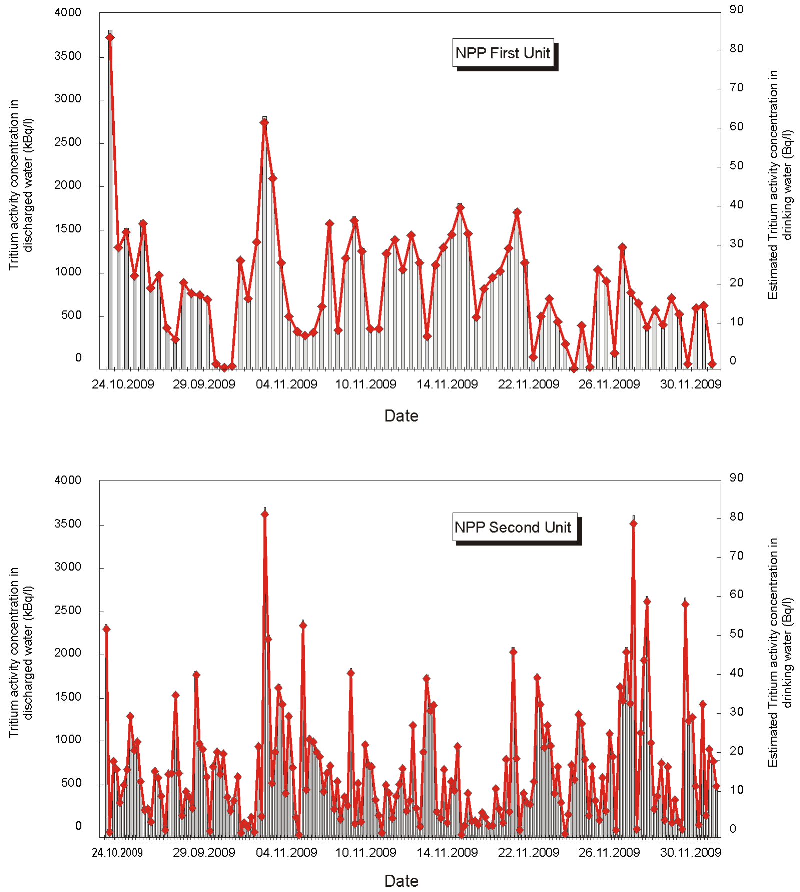

Fig. 2 – Tritium liquid emissions and estimated Tritium concentration in raw water at Unit 1 and 2 during cooling water discharge in the Danube Black Sea Canal.

At the same time, the dilution factor F_{cu} from one cooling water unit to other was equal to 2 while the dilution factor in the Galesu-Palas facility F_u, due to the fact that the treated potable water contains 60 % raw water from Danube Black Sea Canal and 40 % deep underground one was equal to 1.67.

In these conditions, and by using the above dilution factors, the maximum allowed Tritium activity concentration in radioactive effluents discharged from Cernavodă NPP A_{Eff}^{3H} was:

$$A_{Eff}^{3H} = A_{DW}^{3H}\ F_d\ F_{cu}\ F_u, \tag{2}$$

where A_{DW}^{3H} represents the maximum allowed Tritium concentration in potable water equal to 100 Bq/l.

Final calculations gave an overall value of 4.55 MBq/l.

This value was considered as reference for the all administrative measures taken in order not to exceed the 100 Bq/l, the allowed Tritium concentration in drinking water as recommended by EU as well as Romanian legislation [3]. Regarding this aspect, it is worth mentioning that the EU limits are the lowest one with respect to other states [4, 5].

All these assumptions were thoroughly checked during entire monitoring period.

3. MATERIALS AND METHODS

3.1. WATER SAMPLING AND MEASUREMENTS

Water samples collected from the Danube-Black Sea Canal and from the water treatment facility Galesu-Palas were in real time analysed at the Nuclear Power Plant Environmental Control Laboratory and three days later at Constanta Regional Radiation Hygiene Laboratory, the last one belonging to the Ministry of Health.

According to our estimations, the discharge of cooling water with an average debit of 105 m^3/h should determine an increase of water velocity in the Danube Black Sea Canal from 0.047 m/s to 0.18 m/s, so that the wave of cooling water should reach the Galesu-Palas Drinking Water Treatment Plant, situated 64 km downstream off Cernavodă NPP in about 98 hours. For this reason, at Galesu-Palas Plant water samples in this way were collected beginning with 26^{rd} of October 2009.

To determine the activity concentration of Tritium in water, samples of 1 L were collected in a clean polyethylene container. An aliquot of 100 ml of sample was distilled to remove dirt and impurities, then 8 ml of water were added to a vial with 12 ml scintillation cocktail Ultima Gold LLT. Finally, the vial was measured for 24000 s at Quantulus 1220 Liquid Scintillation Counter.

To estimate the influence of diluting with uncontaminated water, the Tritium activity concentrations in drinking water was measured before and after mixing with underground water.

4. RESULTS AND DISCUSSION

The daily variation of the Tritium activity concentrations calculated according to relation (2) and by taking into account the cooling water discharge on both Cernavoda and Galesu Palas facility are reproduced in Fig. As previously mentioned, at both stations, maximum estimated Tritium activity concentration should never overpass 100 Bq/l, but, only direct determination could confirm or infirm these estimation. For comparison, the experimentally determined Tritium activity concentration in drinking water are illustrated in Fig.3. As a general remark, nor at Cernavodă nor

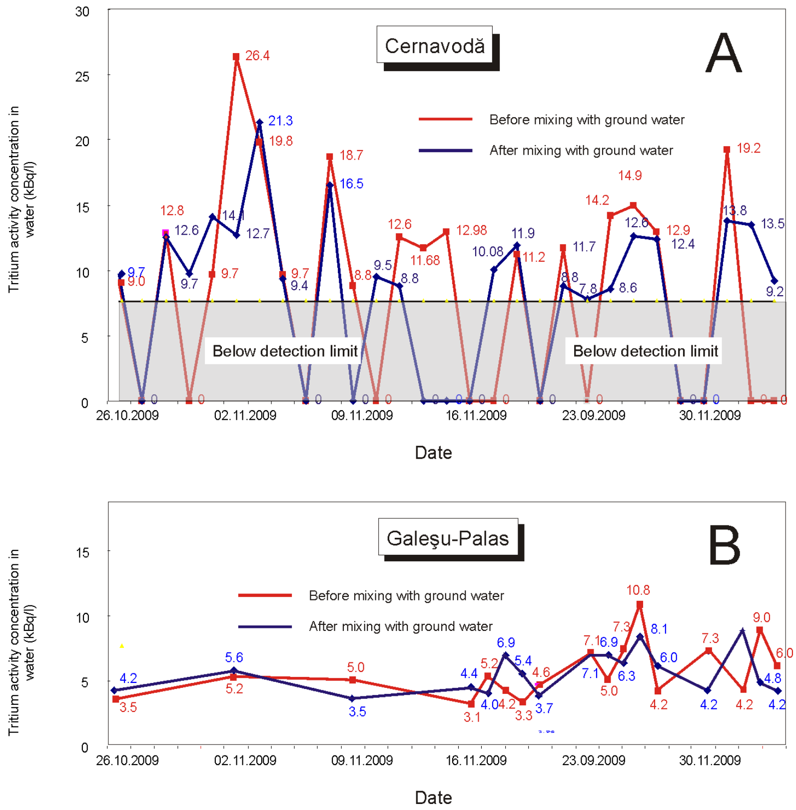

Fig. 3 – Tritium activity concentrations as measured in the Danube-Black Sea Channel near Cernavoda NPP (A) and at Galesu-Palas drinking water facility (B).

at Galesu-Palas collecting points the activity concentration exceeded 28 Bq/l.

Although the discharge of cooling water begun at 22^{th} October, at Cernavodă station Tritium reached the maximum activity concentration at 2^{nd} November, coincident with the maximum discharge of the cooling water (see Fig. 2), while at the Galesu-Palas, the maximum was reached about two weeks later *i.e.*, on 25^{th} November, at a significant lower activity concentration of about 11 Bq/l.

In this way, at both both collecting points, and especially at the Galesu-Palas drinking water facility, the activity concentration of Tritium was less than one third of the maxim admitted value by Romanian Regulation.

The observed discrepancies between calculated end experimentally determined activity concentrations were due, in our opinion, to a significant lower water velocity as previously estimated as well as to a better dispersion of the Tritium containing cooling water in the Danube-Black Sea channel.

5. CONCLUSIONS

Between 22^{nd} October and 9^{th} November 2009, as a result of planned maintenance works at the Cernavodă Nuclear power Plant, the entire volume of cooling water of both units were directed to Danube-Black Sea Channel. In spite the relative high Tritium activity concentration in discharged cooling water, by taking all the necessary measures to minimize radioactive liquid waste production and releases, radioactive content in drinking water was kept well below legal limits, fact confirmed by two independent specialized laboratories. At the same time, the experimentally determined values of Tritium activity concentrations in the Danube-Black Sea Channel were significant lower then the estimated ones, mainly due to some conservative assumptions (*e.g.* water speed along the canal, dilution factors, etc.)

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