Monitoring of atmospheric $^3$H around Kakrapar Atomic Power Station

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Atmospheric tritium activity was measured regularly around Kakrapar Atomic Power Station (KAPS) since gaseous waste which contains tritium is being released through a 100 m high stack at KAPS site. Data collected shows a large variation of $^3$H concentration in air, fluctuating in the range of $\leq 0.2$–19.9 Bq $\cdot$ m$^{-3}$. Significantly, higher tritium levels were measured in samples at the site boundary (1.6 km) of KAPS compared to off-site locations. The atmospheric dilution factor was found to be in the range of 1.1 $\cdot$ 10$^{-7}$–2.9 $\cdot$ 10$^{-7}$ $\text{s} \cdot \text{m}^{-3}$. The scavenging ratio of KAPS site was found to be varying from 0.4 $\cdot$ 10$^4$ to 16.7 $\cdot$ 10$^4$ ($\text{Bq} \cdot \text{m}^{-3}$ rain water per $\text{Bq} \cdot \text{m}^{-3}$ air). The inhalation dose to a member of general public at different distances (1.6–30 km) from KAPS site was found to be 0.07 $\mu$Sv $\cdot$ y$^{-1}$.

Introduction

Tritium, the heaviest and only radioactive isotope of hydrogen, has been a ubiquitous contaminant produced by Pressurized Heavy Water Reactors (PHWRs). The nuclide $^3$H decays to form $^3$He by emission of a beta-particle with a maximum energy of 18.6 keV and an average energy of 5.7 keV. Tritium is one of the most environmentally mobile radionuclides. Therefore, tritium has a high potential for migration into the terrestrial environment by releases to the atmosphere from nuclear facilities. Tritium from nuclear facilities is released into the environment through a 100 m high stack mainly as tritiated water (HTO). The released tritium undergoes dilution and dispersion and then follows the ecological pathway of water molecule. Transfer of tritiated water from the atmosphere to the surface of the earth occurs mainly by precipitation, but also by vapor exchange.

Environmental Survey Laboratory of Health Physics Division, Bhabha Atomic Research Centre (BARC), located at Kakrapar Atomic Power Station (KAPS) site is continuously monitoring the concentration of tritium in the environment to ensure the safety of the public since gaseous radioactive waste which contains tritium is being released through a 100 m high stack at KAPS site. This paper presents the result of analyses of tritium in atmospheric environment covering an area up to 30 km radius around KAPS site. Large number of air moisture samples were collected around the KAPS site, for estimating tritium in atmospheric environment to ascertain the atmospheric dilution and dispersion which will be useful in calculation of radiation dose to the public.

Experimental

Site description

This study was carried out at Kakrapar Atomic Power Station site, situated on the southern bank of Moticher Lake, which is about 85 km by road from Surat city, southern region of Gujarat State (latitude-21° 14’ N and longitude-73° 22’ E). At Kakrapar Atomic Power Station, two pressurised heavy water reactors (PHWRs) having capacity of each 220 MWe are operating since the year 1994.

Sample collection

Air moisture samples were collected at ground level from different villages up to a distance of 30 km (Fig. 1) around KAPS site using condensation method. 395 air moisture samples were collected during the year 2006–2007. During rainy days, rain water samples were collected in a beaker. 4 ml of condensed air moisture or rain water is mixed with 15 ml of scintillator cocktail (consisting of 7.0 g PPO, 0.12 g POPOP and 100 g naphthalene in one liter of 1–4 dioxane solvent). These samples were stored for sufficient time in a dark place before counting. The activity of tritium in the sample is counted using ultra low level liquid scintillation spectrometer (LSS) (Model: Tricarb-3170 TR/SL).

The counting system was calibrated with a tritium standard supplied by Amersham International. The quenching was corrected by the external standard channel ratio method. The chemiluminescence contribution, if any, was automatically subtracted from the total counting rate to obtain a net counting rate...
Ascribable to tritium only. The system background count rate was 1–2 cpm and counting efficiency of LSS system for the detection of $^3$H was about 25%. The detection limit of the present system for $^3$H was estimated to be about 0.2 Bq m$^{-3}$ in air and 10 Bq l$^{-1}$ in water.

**Results and discussion**

$^3$H concentration in atmospheric air moisture

From Table 1, it is observed that out of 395 samples, the $^3$H activity in 274 samples were showing below the detection level (BDL). The atmospheric $^3$H concentration around KAPS site was found to be in the range of $\leq 0.2$–19.9 Bq m$^{-3}$. It is also observed that the median of the $^3$H concentration is consistent over the distance of 30 km from KAPS site. It is of interest to compare the $^3$H concentration in air moisture around KAPS environment with that of other places. MILJEVIC et al.\(^5\) reported the air tritium concentration around Vinca Institute of Nuclear Science, Yugoslavia due to the operation of 6.5 MWth research reactor as 0.27–60.8 Bq m$^{-3}$ in atmospheric water vapor. MATSUURA et al.\(^6\) reported the annual mean tritium concentration in air moisture at three points around JAERI Tokai (having operation of research reactors, tritium-handling facilities, nuclear power plants, and a reprocessing facility) as 0.092–1.1 Bq m$^{-3}$. KIM et al.\(^7\) reported tritium concentration in atmospheric water vapor at two points around Wolsong nuclear power plant, Korea (having two units with the capacity of 629 MWe and 715 MWe) as 0.12–122 Bq m$^{-3}$.

It is reported that the atmospheric conditions such as speed and direction of the wind, rain intensity or stability class, are key factors in the dispersion of tritium in the environment.\(^8\) The variation of tritium concentration in atmospheric water vapor collected at ESL together with atmospheric humidity was studied and it is observed that the $^3$H activity in air is significantly and negatively correlated with humidity. KIM et al.\(^7\) reported the annual mean atmospheric HTO concentration was strongly correlated with the emissions of tritiated water vapor and the correlation coefficients were 0.99 at both locations. In the similar way, the atmospheric HTO concentration at two locations (ESL and Ratania regulator) around KAPS site positively correlated with the release rate of tritiated water vapor from KAPS as shown in Fig. 2, and the linear correlation coefficients were found to be 0.82 and 0.64, respectively. The result suggests that the sample collected from ESL is greatly influenced by the discharged tritium from KAPS through atmospheric route.

![Fig. 1. Map of the investigated area showing sampling locations](image-url)