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The valley system of the Jihlava river and Mohelno reservoir with enhanced tritium activities

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ABSTRACT

The Dukovany nuclear power plant (NPP Dukovany) releases liquid effluents, including HTO, to the Mohelno reservoir, located in a deep valley. Significantly enhanced tritium activities were observed in the form of non-exchangeable organically bound tritium in the surrounding biota which lacks direct contact with the water body. This indicates a tritium uptake by plants from air moisture and haze, which is, besides the uptake by roots from soil, one of the most important mechanisms of tritium transfer from environment to plants. Results of a pilot study based on four sampling campaigns in 2011–2015 are presented and discussed, with the aim to provide new information on tritium transport in the Mohelno reservoir - Jihlava River – plants ecosystems.

1. Introduction

The occurrence of tritium (^{3}H) in the environment has been extensively studied in the last decades. This low energy beta-emitting radionuclide (maximum energy of beta-electrons is 18.6 keV) may cause health effects (Straume and Carsten, 1993), partially also due to its physical and chemical similarity to ^{1}H in H_2O, which allows tritium to occur and enter animal and plant tissues in the form of tritiated water (HTO) (UNSCEAR, 2000). While generated also by cosmic rays reacting with the Earth's atmosphere (Okada and Momoshima, 1993), most of tritium in the environment comes from anthropogenic sources. It is a by-product of the operation of nuclear power plants (NPPs) and nuclear reprocessing plants. Largest amounts of tritium were released during atmospheric bomb tests and NPP accidents (Korolevych and Kim, 2013; Matsumoto et al., 2013; Povinec et al., 2013).

Inhalation, ingestion or absorption through the skin are the ways, which allow tritium to enter the human body. The biological half-life of tritiated water is only about 10 days, so it can be removed from the human body relatively fast. However, the retention time of non-exchangeable organically bound tritium (NE-OBT) can be much longer (Diabaté and Strack, 1993; Guénot and Bélot, 1984; Hunt et al., 2009; ICRP, 1997).

When dealing with tritium in biota, several chemical forms of its occurrence have to be considered. Particularly, tissue free water tritium (TFWT) and organically bound tritium (OBT). Tritium can in principle be bound in various organic compounds – either to oxygen and nitrogen atoms as the exchangeable organically bound tritium (E-OBT, considered in equilibrium with HTO in the tissues), or bound to carbon atoms as NE-OBT (Baglan et al., 2011; Baumgartner and Donhaerl, 2004; Diabaté and Strack, 1993; Guénot and Bélot, 1984; Pointurier et al., 2003, 2004). TFWT values are more influenced by short-term fluctuations in tritium input, whereas the NE-OBT values represent a long-term activity level. Both parameters are suitable for routine laboratory measurements (Baglan et al., 2008; Jean-Baptiste et al., 2010; Kakiuchi et al., 2011; Sweet and Murphy, 1984; Vichot et al., 2008).

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An interesting system for tritium studies in the environment can be found in the vicinity of the Dukovany NPP – the older of the two NPPs operating in the Czech Republic. This NPP is equipped with four 440 MW light water pressurised reactors. In surface waters in the surroundings of Dukovany, tritium has been monitored since 1985 (start of the NPP's operation). Measurements of organically bound tritium commenced in 2011 and continued until 2015 (Kořínková et al., 2015; Svetlik et al., 2014). The pilot study discussed in this paper is based on four sampling campaigns with the main goal to provide basic knowledge on enhanced NE-OBT activities in the vicinity of the Mohelno reservoir and the effluent part of the Jihlava river, together with a brief description of this system. In the present publication we are discussing results gathered in 2015 sampling campaigns and comparing them with our previous investigations (Kořínková et al., 2015; Svetlik et al., 2014).

2. Hydrological background and methods

2.1. Basic description of the Mohelno reservoir and effluent part of the Jihlava river

The system of the Dalešice (1.3 10^8 m^3) and Mohelno (1.7 10^7 m^3) reservoirs on the Jihlava river (Q_a[1] = 6.3 m^3 s^{-1}) is situated in a narrow, deep valley with limited ventilation. This valley terminates before Ivančice, near the confluence of the Jihlava river with the Oslava river ($Q_a = 3.5$ m^3 s^{-1}). The Jihlava river then flows into the Svratka river ($Q_a = 12$ m^3 s^{-1}), which, together with the Dyje river ($Q_a = 12$ m^3 s^{-1}) and smaller other rivers/creeks, discharges to the Nové Mlýny reservoir system (three reservoirs, where the Svratka river enters the middle lake, with the total volume of 5.1 10^7 m^3). The Dyje river flows out from the Nové Mlýny reservoirs ($Q_a = 41$ m^3 s^{-1}) (PMO, 2015). Behind the Mohelno reservoir, the Jihlava river flows through sharply cut valleys in granulite with only rare occurrence of fluvial sediments. From Ivančice to the Nové Mlýny reservoirs there is a wide alluvial plain formed predominantly by sediments of Holocene age (CGS, 2015).

The average annual temperature is between 8 and 9 °C and the rainfall 550–600 mm $year^{-1}$ (CHMI, 2015). Some parts of the valley edges and slopes are covered by thermophilous oak forests. On serpentine outcrops, dry pine forests can be found, as well as natural forest-free areas with dry grasslands or shrub formations and other thermo- and xerophilous basophilic vegetation. On the slopes deeper in the valley, the thermophilous associations are replaced by ravine forests, dominated by maples and hornbeams (Aceri-carpinetum). On the bottom of the valley, it is possible to find alder carrs, alluvial mesophilic meadows, reeds and nitrophilous vegetation of wet habitats. These vegetation types occur also in the part between Slavětice and Nové Mlýny. This section of the riverside and, likewise, the plateaus above the valley, also contain a substantial proportion of ruderal habitats and agrobiocenoses (Chytrý and Rafajová, 2003).

The Dukovany NPP is taking cooling water from the Mohelno reservoir on the Jihlava river and, subsequently, releases the liquid effluents into the Skryjský creek which runs back into Mohelno, just several tens metres from the water inlet. Thus, a part of the HTO from the liquid discharges re-enters the NPP, thus creating a “loop” effect. Finally, a part of the (tritiated) cooling water is evaporated into the atmosphere, Fig. 1 (Duran and Malátová, 2010; Svetlik et al., 2014).

Tritium activity concentrations (HTO) in the Mohelno reservoir and in the releasing part of the Jihlava river are about 70 Bq L^{-1} (ten-year average), although values exceeding 200 Bq L^{-1} were also observed there. The data from cooling water show similar mean activities, although more distinct oscillations (connected with the “loop” effect) are visible in both time series (Duran and Malátová, 2010; Svetlik et al., 2014; Kořínková et al., 2015). The corresponding annual dose to public from liquid tritium releases from the Dukovany NPP is about 1.8 10^{-6} Sv, below the authorized limit of 6.10^{-6} Sv, given by the national regulatory (SONS, 2015a).

2.2. Sampling

Biota sampling for analysis of NE-OBT and TFWT in the surroundings of the Mohelno reservoir and in the valley of the Jihlava river was performed during four one-day campaigns: (a) 10th August 2011 (pilot analysis), 5 biota samples were collected at the localities #1 and #3; (b) 19th December 2014, 7 samples were collected at the locality #2, and 5 samples at the locality #3; (c) 20th July 2015, 13 samples were collected at the localities #1 (sampling time ca. 11 a.m. CEST), #4, 5, 7–11 (sampling took place between 1 p.m. and 7 p.m. CEST); (d) 26th August 2015, 11 samples were collected at the localities #1 (sampling time 11 a.m. CEST), #3 (sampling time 12 a.m. CEST), #4, #6–8 (sampling took place between 2 p.m. and 6 p.m. CEST).

Within the frame of the individual sampling campaigns, water samples for measurements of HTO activity were also taken from each of the localities. Moreover, water sampling (without biota) from the localities #11 and #12 was performed during the third campaign as well.

The first campaign: The aim of this sampling was to verify if plants without direct contact with the reservoir/river water exhibit significantly enhanced NE-OBT activities in comparison to the background level, which is less than 2 Bq L^{-1} in rain and surface water (Svetlik et al., 2014). Therefore, three samples were taken from the locality #1, and two samples from the locality #3. No TFWT analyses were performed for the samples from the first campaign.

The second campaign: Our selection of aquatic, forest and pratal plant species in locality #2 was pursuing the goal to obtain a series of samples covering the distances from 0 to about 100 m from the water surface. In locality #3 we focused on samples of aquatic and pratal plant species, which were close to the water surface, covering the distances from 0 to about 8 m (Kořínková et al., 2015). We showed what possible effect the gradient of the slopes can have on tritium intake by plants near the reservoir and river.

The third and fourth campaign: In both of these campaigns, sampling of plant species and surface water was aimed especially on obtaining information about NE-OBT distribution in the valley of the Jihlava river, which continues from the Mohelno to the Nové Mlýny reservoirs. Sampling for the third campaign was covering the part between the Mohelno reservoir and the discharge of the Jihlava (Svratka[2]) river into the Nové Mlýny reservoirs system (localities #1–10). The fourth campaign focused mainly on the deep part of the Jihlava river valley down to the confluence with the Oslava river (localities #1, 3, 4, 6–8).

During the third and fourth campaign, no precipitations were observed on the site. According to the data from the Zbyšov observatory (ca. 5 km north of the town Ivančice), the weekly rainfall totals before the third and fourth campaign were 13.4 mm and 9.0 mm, respectively. The wind direction was north-west (average windspeed 1.7 m s^{-1}) during the third campaign and south-west during the fourth campaign (0.4 m s^{-1}), for details see IAP CAS (2015). However, we could observe local changes of the wind direction caused by the morphology of the valley.

[1] Annual average value.

[2] Behind the confluence this water continues under the name Svratka river.