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Penetration of tritium into ground water in the Czech Republic

Eva Juranová*, Barbora Sedlářová, Diana Marešová, Irena Pohlová

T. G. Masaryk Water Research Institute, public research institution, Podbabská 30/2582, 160 00 Prague 6, Czech Republic

*corresponding author:
e-mail: eva.juranova@vuv.cz

Abstract

Tritium (^{3}H), the radioactive hydrogen, can form naturally by interaction of the cosmic radiation with the atmosphere, or it can be produced by human activities. In recent, tritium occurs distributed in environment in low concentrations, which means no significant health risk, but it can be used for tracing purposes. In the Czech Republic, tritium was monitored in ground water samples together with the samples of precipitation, using the method of liquid scintillation analysis with electrolytic enrichment. The average value of the tritium concentration in ground water was 0.57 Bq/l, which is lower than the average value evaluated for precipitation (0.97 Bq/l). This is caused by the radioactive decay of tritium in ground water, where the connection with the surface is limited. The results of this tritium monitoring can be used for estimation of the surface influence onto the ground water and for the assessment of ground water vulnerability.

Keywords: Tritium, Radioactivity, Ground Water, Precipitation, Infiltration

1 Introduction

Tritium is a radioactive isotope of hydrogen with a half-life of 12.3 years. It can form naturally by interaction of the cosmic radiation with the atmosphere, or it can be produced by human activities. Tritium is released during the operation of nuclear facilities and its concentrations in the environment are still affected by the atmospheric nuclear testing, too (UNSCEAR, 2000).

Thanks to its presence in environment and its favorable properties, tritium is used as a radiotracer. It can be used to evaluate the migration and retention time of ground water (Kanduc et al., 2014; Ako et al., 2013). It is widely used for estimation of groundwater mean residence and in modelling of pollutant transport in groundwater (Cox Tet al., 2013; Morgenstern et al., 2010) or for determination of origin of waters (Gorur, 2012). For that the fact that tritium is present in a certain amount at the Earth surface and, as it is transported to the ground, its amount decreases due to its radioactive decay.

In this study, tritium in ground water was monitored in the Czech Republic for the purpose of the ground water vulnerability determination.

2 Methods

For the tritium monitoring, ground water samples were collected from selected boreholes all over the territory of the Czech Republic in 2020. 80 ground water samples were collected and analyzed for tritium. In addition, the precipitation samples were collected monthly at two stations (Podbaba and Kocelovice), during the whole year 2020 to determine the surface tritium concentration. The sampling points are displayed in the map in the **Figure 1**.

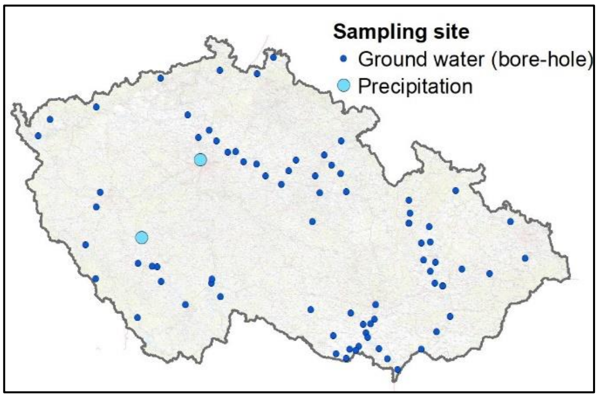

Figure 1 Sampling sites for ground water and precipitation samples collection.

For the tritium determination in ground water and precipitation samples, the method of liquid scintillation spectroscopy according to the EN ISO 9698 (2019) was employed. Since determination of very low levels of tritium is essential for this study, the tritium electrolytic enrichment (Marešová, 2019; Marešová, 2017) was used for the samples, which enabled to reach the determination limit as low as 0.05 Bq/l.

3 Results and discussion

3.1 Tritium in precipitation

In the precipitation, the average tritium concentration was 0.97 Bq/l, the values ranged from 0.5 Bq/l to 1.9 Bq/l. The difference between the tritium concentration in Kocelovice and Podbaba was statistically insignificant (see

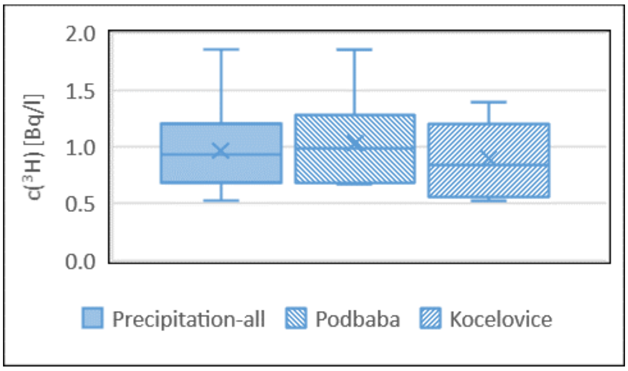

Figure 22).

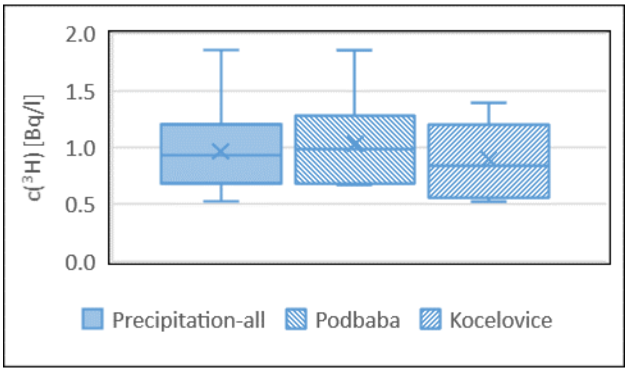

Figure 2 Tritium activity concentration in precipitation.

The measured values are in harmony with the data collected in Global Network of Isotopes in Precipitation (IAEA/WMO, 2021) and other findings (Chau et al., 2011) that typical tritium concentrations detected nowadays in mid-latitude continental precipitation are in the order of 1 Bq/l. Hanslík et al. (2002) reported values around 1.5 Bq/l in precipitation in the Czech Republic in the years 1999-2000.

3.1 Tritium in ground water

In the ground water, the tritium activity concentration varied from the minimal value <0.05 Bq/l to the maximum 11.1 Bq/l. This highest value was measured at the Přítluky site, and it is supposed to be influenced by infiltration of tritium from the Jihlava River, where the tritium concentration is elevated due to releases from the Dukovany nuclear power plant. The next highest tritium concentration measured in ground water was 0.95 Bq/l, which corresponds to an intensive communication with precipitation water. On the other hand, the minimal tritium concentration values (<0.05 Bq/l) indicate a very limited penetration of precipitation or surface water into the ground water bodies. The average value of tritium concentration in the ground water was 0.57 Bq/l with the standard deviation 0.21 Bq/l (excluding the Přítluky site). Only five samples (out of 80) were below the method detection limit. The cumulative distribution of the measured tritium concentration is shown in the

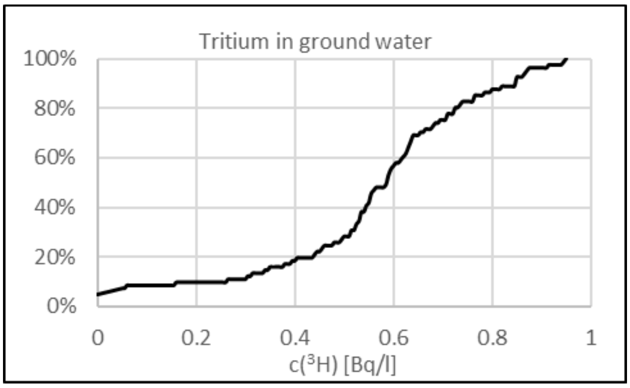

Figure 33.

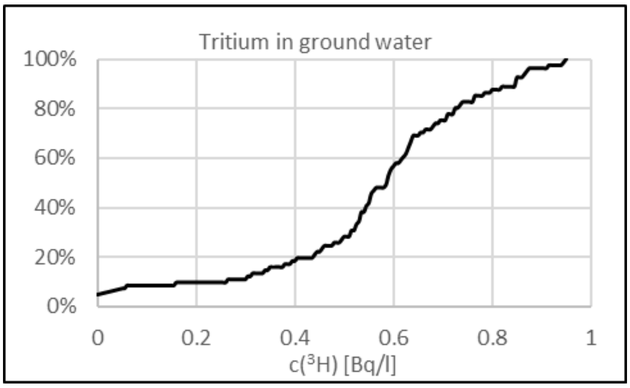

Figure 3 Relative cumulative frequency of tritium concentration in ground water samples.

3.1 Tritium concentration versus the bore-hole depth

The depth of the bore-hole, from which the ground water samples were collected, was considered to be the basic parameter influencing the communication of the ground water with surface. The depths of the bore-holes, wherethe samples were collected, varied from 5 m up to 33 m, one bore-hole was as deep as 70 m. In 13 cases, the depth was not known.

The samples were divided into four groups, according to the measured tritium concentration and the depth of the bore-hole:

- H/S - High tritium concentration (higher than 0,5 Bq/l) and shallow bore-holes (shallower than 20 m)
- L/D – Low tritium concentration (lower than 0,5 Bq/l) and deep bore-holes (deeper than 20 m)
- H/D - High tritium concentration (higher than 0,5 Bq/l) and deep bore-holes (deeper than 20 m)
- L/S - Low tritium concentration (lower than 0,5 Bq/l) and shallow bore-holes (shallower than 20 m)

Distribution of bore-holes among these four groups is illustrated in

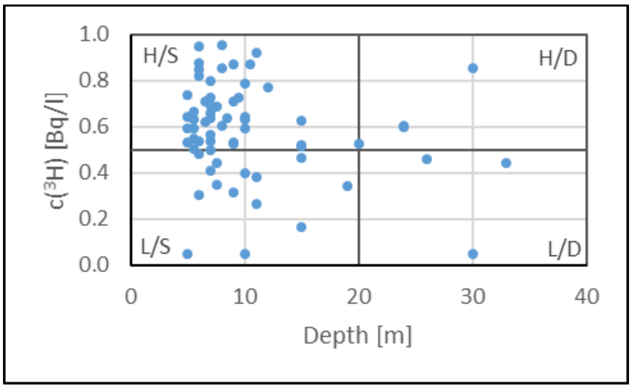

Figure 44. The most numerous is the group H/S, where the elevated tritium concentration indicates communication of ground water and surface. In this group, 42 bore-holes were classified. In the next group L/D (low tritium, deep), four bore-holes were classified. In these deep bore-holes, the penetration of tritium is very limited and the ground water is well protected from the outer contamination, according to the expectation.

On the other hand, the premise of relation between the bore-hole depth and tritium concentration is infracted at the L/S and H/D groups, where four and 16 bore-holes are classified, and it is necessary to search for reasons. For the L/S group, where shallow bore-holes with low tritium concentration were classified, that is the fact that the overlying layers are compact and dense enough to separate the ground water from the surface effectively. The opposite explanation can be used for the H/D group: the overlying layer, despite being thick, has structure, which allows penetrating of surface influences deep into the ground water.

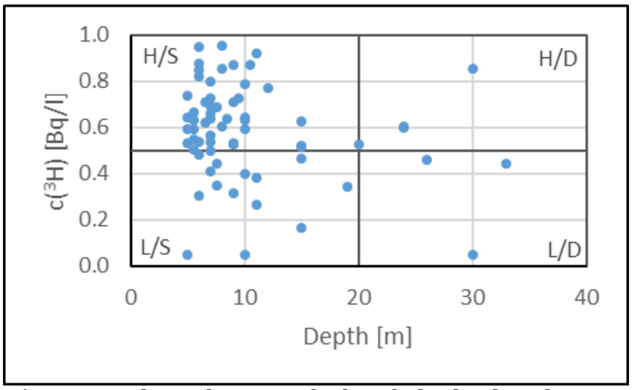

Figure 4 Relation between the borehole-depth and tritium concentration in ground water

4 Conclusion

It was shown that penetration of tritium from surface can be significant not only in shallow ground waters but also in deep ground water bodies in some cases. The depth of the ground water body itself does not mean its good protection against the outer contamination from surface. Other influences may play role then, like the character of the overlying structure. The study will continue for improvement of the findings.

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