Health risk assessment method for drinking water containing tritium oxide

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INTRODUCTION

A lot of radiation-dangerous objects (RDO) available in the world and the economic activity have generated some pressing problems for human health and the environment. Obninsk was founded on the basis of a large town-forming object (State Scientific Centre of the Russian Federation the “Institute of Physics and Power Engineering” (IPPE) of the Federal Agency for Nuclear Power Engineering). Development of nuclear technologies, the available centers of utilization, reprocessing and disposal of radioactive materials and wastes have governed the need for studying technogenic radionuclide behavior and migration in our region. A particular emphasis should be placed on the problem of environmental pollution with tritium.

The above sources of natural and anthropogenic tritium have formed background levels of this radionuclide in Russia and the adjacent water area. According to long data, tritium content in the seas surrounding Russia varies within 4–10 Bq/l with a pronounced downward tendency. Background levels of Russian river pollution with tritium are 2–7 Bq/l, the averaged Russian values being within 4 Bq/l (Makhon’ko, 1998).

In 1995 when testing groundwater sources of the Protva left bank where all Obninsk enterprises are placed, the SPA “Typhoon” employees had found that the higher tritium content was observed at all outlets of groundwater sources in the sanitary zone of Obninsk water intakes, including those upstream of the town and NPP (Makhon’ko, 1996). Maximum tritium concentrations up to 46.9 kBq/l refer to water in the first above floodplain terrace of Protva near the new IPPE radioactive waste (RAW) repository (Makhon’ko, 1996). For comparison, according to the Russian RSS-99 (Radiation safety standards RSS-99, 1999) the intervention levels for inorganic tritium compounds are 7700 Bq/l and for organically bounded tritium 3300 Bq/l.


MATERIALS AND METHODS

Monitoring of tritium dispersal at the IPPE industrial site and near Obninsk had been performed by analyzing tritium content in the reference wells of the RAW repository, water and snow in the IPPE area and adjacent territories and water from four Obninsk water intakes.

Water from the wells under control was taken with a special sampler. Snow at each selected site was sampled to the total depth of snow into plastic packs. Then snow was melted at a room temperature and this water was placed into tight vessels. Samples were analyzed after filtration and distillation.

Results of water sample measurements were obtained by Moscow Physics and Engineering Institute’s laboratory and by the external monitoring laboratory of Smolensk NPP with the help of a precision liquid-scintillation beta-spectrometer Gardian 1414-03 (Wallac Oy,
RESULTS AND CONCLUSIONS

Hazard identification

Table 1 presents data on tritium content in snow and water of nine springs and water sources of Obninsk and its neighbourhoods.

<table>
<thead>
<tr>
<th>Sampling site</th>
<th>Specific activity of $^3$H, Bq/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>Springs, Obninsk neighbourhood</td>
<td>1 ÷ 24</td>
</tr>
<tr>
<td>Springs near the IPPE industrial site</td>
<td>6290 ÷ 37 000</td>
</tr>
<tr>
<td>Observation well №5 (the IPPE industrial site)</td>
<td>6720</td>
</tr>
<tr>
<td>Snow (the IPPE industrial site)</td>
<td>9 ÷ 168</td>
</tr>
<tr>
<td>Snow (Obninsk, out of the IPPE industrial site)</td>
<td>&lt;1 ÷ 4</td>
</tr>
<tr>
<td>Central water intake</td>
<td>291</td>
</tr>
<tr>
<td>Samsonovo water intake</td>
<td>102</td>
</tr>
<tr>
<td>Vashutino water intake</td>
<td>4</td>
</tr>
<tr>
<td>Obninsk water supply network</td>
<td>2 ÷ 80</td>
</tr>
<tr>
<td>The intervention level</td>
<td>7700</td>
</tr>
</tbody>
</table>

Table 1 shows that the maximum value of volume activity for groundwater is 37 000 Bq/l, that is five times as much as the intervention level (7700 Bq/l). The highest tritium activity is observed in the Central water intake (next to the IPPE industrial site) and amounts to about 300 Bq/l that is almost seventy five times as much as the Russian background levels but below the intervention level. In other wells of Obninsk water supply the specific activity of tritium ranges within 1–25 values of the background level (4 Bq/l). In springs near the industrial site there is an excess of the tritium intervention level for drinking water. The volume tritium activity in snow varies from the background values in Obninsk to about 168 Bq/l. It is seen that tritium ingress with snow water reduces tritium concentration in the groundwater bearing horizons in wells and increases the background radioactive pollution with tritium in the IPPE territory.

To supply a town with water, a series of water intakes is built 5–10 km distant from the IPPE industrial site which take water from Protva and Oka-Tarusa water bearing horizons. Recently, technogenic tritium has been found in some water intakes

Exposure assessment

To assess the absorbed dose $D_{\beta}$ in chronic radionuclide ingress, a one-chamber model is chosen of tritium transfer and distribution in human organism. Accordingly, an equation of time dependence for the absorbed dose is obtained.

$$D_{\beta}(t) = 2.0 \cdot 10^{-3} \cdot \frac{E_{\beta} \cdot A \cdot V \cdot f \cdot T_{0}}{m} \left( t + \frac{T_{0}}{e^{0.693} - 0.693} \right),$$

Where $E_{\beta}$ – average energy $\beta$-rays on decay, MeV; $A_v$ – volumetric activity of tritium in potable water, Bq/l; $V$ – speed of intake of potable water, l/day; $f$ – factor of tritium transition
in critical organ; \( m \) – weight of a body of the person, year; \( T_{ef} \) – effective half-life, with; \( t \) – time of tritium intake in an organism, days.

Relative biological efficiency (RBE) of internal tritium \( \beta \)-radiation is 2. In exposure the critical organ is the whole body. With this in view, calculated are the absorbed, effective (E) and collective (S) doses of human exposure: E is \( 0.44 \div 3.74 \mu \text{Sv/year} \); S varies from \( 2.84 \times 10^{-4} \) to \( 15 \times 10^{-2} \) men·Sv/year. The value of E dose received by every man during a year ranges from 0.04 to 0.37 % of the population standard (1 mSv/year). Hence, the value of internal human exposure from tritium radiation is insignificant. This is, however, the case of low doses, the effect of which is anomalous.

**Risk characterization**

Now practically all countries and international organizations consider the concept of risk assessment as the primary mechanism in decision making at the international, state or regional level as well as the level of an isolated industry or any other contamination source potentially dangerous for the environment. In our case considered is the health or life risk from technogenic tritium available in the environment.

Radiation risk has been assessed to determine the degree of human impact of the above tritium activity in drinking water. In calculating the life risk coefficients given in RSS-99 (Radiation safety standards RSS-99, 1999) and the technique described by Synzynys et al. (2005) were used. When drinking water with the activity of 67 Bq/l the annual effective per capita dose for Obninsk inhabitants is 1.48 \( \mu \text{Sv} \) that corresponds to the individual life risk of stochastic effects \( 1 \times 10^{-7} \) year\(^{-1} \). The obtained risk value is by an order of magnitude lower than the acceptable risk \((1 \times 10^{-6})\) recommended by the World Health Organization. Thus, under stable conditions at the municipal water intakes there is no need for local authority interference to limit the impact of a considered risk factor.

Moreover, according to ICRP recommendations (Publication 60), the risk is calculated of extra lethal cases from tritium available in drinking water. For different population categories the life risk varies from \( 2.2 \times 10^{-8} \) to \( 1.5 \times 10^{-7} \) for lethal cancer; \( 4.4 \times 10^{-9} \) to \( 3.0 \times 10^{-8} \) for nonlethal cancer; \( 2.6 \times 10^{-8} \) to \( 1.8 \times 10^{-7} \) for all malignant tumors and \( 4.4 \times 10^{-9} \) to \( 2.8 \times 10^{-8} \) for inherited (genetic) effects. These values are below the individual life risk standard for Russia, i.e. \( 5.0 \times 10^{-5} \).

The method developed is a combination of chemical and radiation risk assessments which allows the health consequences for people drinking water with tritium to be forecasted. A new methodology may be also useful for risk assessment of other radionuclides.

**ACKNOWLEDGEMENT**

Research is carried out at financial support of the Ministry of education, culture and sports of the Kaluga region.

**REFERENCES**

