ASSESSMENT OF CARCINOGENIC RISK OF DRINKING SURFACE WATER CONSUMPTION OF THE TRANSBOUNDARY BASIN OF THE SELENGA RIVER IN THE TERRITORY OF MONGOLIA

Dr. Irina Ulzetueva[1]
Prof. Bair Gomboev[2]
Dr. Daba Zhamyanov[3]
Dr. Valentin Batomunkuev[4]
Dr. Natalia Gomboeva[5]
[1, 2, 3, 4] Baikal Institute of Nature Management SB RAS, Russia
[2, 5] Banzarov Buryat State University, Russia

ABSTRACT

The assessment of the carcinogenic risk of the impact of drinking surface waters on the population health of the transboundary basin of the Selenga river in Mongolia is described in the article. We carried out expeditionary studies of the quality of drinking surface waters on the territory of four aimags, which represent different degrees of economic development and are completely included in the Selenga river basin: Khuvsgul, Arkhangai, Bulgan and Selenge. In this work, we used the methodology used by the US Environmental Protection Agency to quantify the carcinogenic risk of exposure to chemical compounds present in surface waters using the example of these aimags in Mongolia. The application of this methodology for risk assessment gives a great advantage over traditional methods of regulation. It has been established that on the territory of the Selenge aimag, the risk of developing a carcinogenic effect from the impact of priority pollutants on public health associated with the quality of drinking water is high and in the territory of Bulgan, Khuvsgul and Arkhangai aimags are medium, which requires state regulation of the risk and the development of appropriate standards.

Keywords: *transboundary basin of the Selenga river, anthropogenic factors, risk assessment, drinking water*

INTRODUCTION

The study of water quality is the most important subject of study in territories with transboundary water bodies. In connection with the intensively growing anthropogenic load on surface waters as a result of economic development, the main task in the implementation of the state policy of each country in the field of water sources protection is to ensure human health and well-being. [1].

The transboundary basin of the Selenga river is located on the territory of two states - Mongolia and Russia. The Selenga river originates from the confluence of the two rivers Ider and Delger-Muren on the territory of Mongolia, and flows into the lake Baikal on the territory of Russia. The Selenga river basin in Mongolia includes: the Capital Region (Ulaanbaator) and territories of 11 aimags, of which four are included in the basin only in minor parts (Khentii, Zavkhan, Bayankhongor, Uvurkhangai). The rest entirely cover the territory under consideration: Khuvsgul, Arkhangai, Bulgan, Orkhon, Selenge, Darkhan-Uul, Tuv (Central). We carried out expeditionary studies of the quality of drinking surface waters on the territory of four aimags, which represent different degrees of economic development and are completely included in the Selenga river basin: Khuvsgul, Arkhangai, Bulgan and Selenge.

Analysis of literature data shows that the most promising approach to ranking influencing environmental factors of various nature is the concept of health risk assessment [2]. Health risk assessment refers to the process of establishing the likelihood of development and the severity of adverse effects on human health or the health of future generations due to the impact of environmental factors (WHO, 2000). It also includes damage to the population within statistical limits justified by environmental, technical or other considerations. The US Environmental Protection Agency (EPA US) characterizes risk as "the likelihood of injury, illness, or death under certain circumstances" [3]. The results obtained from the concept of risk are usually presented either as upper limits of additional risk (the expected incidence of disease from exposure to pollutants at a given concentration), or as upper levels of concentration of pollutants at a given level of risk. In this case, it is not a safety threshold that is set, but an acceptable threshold, i.e. limit, beyond which one cannot go.

METHODS AND METHODOLOGY

In this work, we used the methodology used by the US Environmental Protection Agency [1-3] to quantify the carcinogenic risk of exposure to chemical compounds present in surface waters using the example of these aimags in Mongolia. The application of this methodology for risk assessment gives a great advantage over traditional methods of regulation, which are based on comparing the levels of actual pollution and the standard values of these pollutans in the development of health-improving measures. The methodology also allows one to obtain quantitative characteristics of the real and potential damage to public health from the effects of pollution of surface water sources within the framework of a single decision-making process, based on which measures to reduce the risk are determined along with restrictions on resources and time. With the help of this technique, a forecast of the situation is carried out, namely, the calculations of the risk for the current situation and for the future are carried out. This is of great practical importance in the organization of sanitary protection zones of industrial enterprises, reclamation of contaminated areas, assessment of action plans, protection of water sources from pollution, especially in the context of intensively developing mining.

The calculation of the lifetime carcinogenic risk (Risk) was calculated by multiplying the average daily dose (ADD) (or average daily intake) for the entire period of life by the value of the relative carcinogenic strength of inorganic compounds SF_0 (the factor of carcinogenic potential for a carcinogen):

$$Risk = ADD \times SF_0 \quad (1),$$

where the Risk value characterizes the upper limit of the carcinogenic risk for the average life expectancy of the population [4]. To calculate the exposure doses, the recommended standard values of human physiological constants for the oral route of exposure were used, developed by IARC (International Agency for Research on Cancer) and WHO (human weight (BW) - 70 kg, average volume of daily consumed water (DW) - 2 l/day). Thus, the Risk value is an estimate of the risk of developing a neoplasm over the average life span of a person.

In many countries of the world, the classification of individual life-long risk, recommended by WHO (World Health Organization) in 1996, 1999, 2000, is adopted, as well as approved by a number of methodological documents of a number of foreign countries [5]: high risk>10^{-3}, average risk 10^{-3} -10^{-4}, low (acceptable) risk 10^{-4}-10^{-6}, minimum (desirable) target risk <10^{-6}.

DISCUSSION

According to analytical data provided by the Mongolian hydrometeorological service, as well as data obtained during expeditionary operations in Mongolia [6], priority pollutants were identified on the content of inorganic substances in drinking surface waters of four aimags. To assess the exposure, five chemicals with proven carcinogenic properties were selected, which were found in drinking water samples (chromium, arsenic, cadmium, nickel and lead). For these substances, the carcinogenic risk to public health was calculated during their consumption. Due to the fact that multicomponent chemical pollution of drinking surface waters is present in the study area, it becomes necessary to study the total risks caused by the simultaneous complex effect of several chemicals and compounds at once during their oral intake. Consequently, within the framework of the risk assessment methodology, the combined effect of carcinogens is usually considered additive.

Data on the relative carcinogenic strength of inorganic compounds (SF_0) and their content in drinking and surface waters in a number of aimags of Mongolia that pollute water are given in the table 1.

Table 1. *Carcinogenic potential contaminants SF_0, and their content is, for drinking and surface waters Mongolia*

Compound	SF_0 (mg/(kg×day))$^{-1}$	C, mg/l×10^{-3}									
		Aimag									
		Bulgan		Selenge			Khuvsgul				Arkhangai
		C_{min}	C_{max}	$C_{med.}$	C_{min}	C_{max}	$C_{med.}$	C_{min}	C_{max}	$C_{med.}$	C_{max}
Chromium	0.42	3.6	3.7	3.65	3.6	29	10.12	3.6	3.6	3.6	3.6
Arsenic	1.5	2.1	4.3	3.03	2.1	31	10.2	2.1	3.9	2.57	3.8
Cadmium	0.38	6.2	11,2	7.86	2.7	13	7.15	0.38	11,0	6.07	11,1
Nickel	1.7	0.18	0.24	0.2	0.21	2.2	0.69	0.04	0.2	0.11	0.09
Lead	0.047	0.66	2.13	1.1	0.72	3.1	2.2	0.05	0.56	0.7	0.09

According to the table 1, the content of arsenic of the Selenga aimag and cadmium in the waters of all the considered aimags in drinking surface waters indicate an excess of their normative content in drinking water, adopted by the water quality standard in Mongolia [7].

The results of calculating the carcinogenic risk from the consumption of water containing inorganic toxicants are shown in table 2. The total risk was calculated using the usual additive scheme (tab. 2).

Table 2. *Values of carcinogenic risk (Risk) for water consumption which are containing pollutants in the aimags of Mongolia, 10^{-4}*

Compound	Risk*									
	Aimag									
	Bulgan			Selenge			Khuvsgul			Arkhangai
	Risk min	Risk max	Risk med.	Risk min	Risk max	Risk med.	Risk min	Risk max	Risk med.	Risk max
Chromium	0.432	0.444	0.438	0.432	3.480	1.214	0.432	0.432	0.432	0.432
Arsenic	0.900	1.843	1.299	0.900	13.286	4.371	0.900	1.671	1.101	1.629
Cadmium	0.673	1.216	0.853	0.293	1.411	0.776	0.041	1.194	0.659	1.205
Nickel	0.087	0.117	0.097	0.102	1.069	0.335	0.019	0.097	0.053	0.044
Lead	0.009	0.029	0.015	0.010	0.042	0.030	0.001	0.008	0.009	0.001
Total risk	2.101	3.626	2.702	1.737	19.287	6.727	1.393	3.402	2.255	3.300

*Note. $Risk_{min}$ - additional carcinogenic risk at the specified minimum concentration of the compound in drinking water;

$Risk_{max}$ is an additional carcinogenic risk at the specified maximum concentration of the compound in drinking water;

$Risk_{med}$ is an additional carcinogenic risk with an average content of the compound in drinking water.

Data analysis of the table 2 shows that for the considered inorganic compounds, the highest risk levels correspond to chromium ($Risk_{max}$=3.48×10^{-4}) for the Selenge aimag, which is equivalent to 348 cases of neoplasms per 1,000,000 people; for arsenic ($Risk_{max}$ = 13.3×10^{-4}, 1.84×10^{-4}, 1.67×10^{-4}, 1.63×10^{-4}) for the Selenge, Bulgan, Khuvsgul, Arkhangai aimags, respectively; for cadmium ($Risk_{max}$=1.41×10^{-4}, 1.22×10^{-4}, 1.2×10^{-4}, 1.19×10^{-4}) of the Selenge, Bulgan, Arkhangai, Khuvsgul, aimags, respectively, and for nickel ($Risk_{max}$=1.07×10^{-4}) for the Selenge aimag.

With the combined action of all substances, the minimum total carcinogenic risk ($Risk_{min}$=1.393×10^{-4}) is typical for the Khuvsgul aimag, the maximum total carcinogenic risk ($Risk_{max}$=19.297×10-4) is for the Selenge aimag. According to the WHO classification, this corresponds to an average and high level of risk.

Thus, the greatest likelihood of a carcinogenic risk of a (up to 1929 cases per 1,000,000 people) with oral water consumption arises for the Selenge aimag population.

It should be noted that arsenic has a proven carcinogenic effect and, subsequently, constant consumption of drinking water with an established arsenic content can cause chronic diseases, as well as the development of oncological diseases. Drinking water contaminated with arsenic is the cause of lung diseases, including respiratory failure, lung cancer, bronchiectasis. The action of arsenic through drinking water on the body of children at an early age or in the womb can lead to pulmonary pathology and this leads to a significant increase in mortality among young people from cancer and bronchiectasis [8].

CONCLUSION

As a result of the studies carried out, it was established that in the territory of the transboundary basin of the Selenga river in surface waters, the content of arsenic and cadmium in the territory of the Selenge aimag exceeds their hygienic standards. The calculation of the total carcinogenic risks showed that the studied surface drinking water, subject to their constant long-term use in Bulgan, Khuvsgul and Arkhangai aimags, form the medium permissible levels of carcinogenic risk for the population health, and in the Selenge aimag they are high. At the same time, the sectoral structure of the economy in the Selenge aimag is also associated with the extraction of minerals, which contributes to the flow into the surface waters of the river basin. Selenga of the specified substances with industrial wastewater. High concentrations of cadmium and arsenic in drinking waters of the transboundary basin of the Selenga river cause high risks of developing diseases, which in turn determines these waters as unsuitable for economic and drinking use by the population, accordingly, certain measures are required to reduce health risks. The data obtained indicate the need to develop a methodology for state risk regulation and the development of appropriate standards, while it is necessary to take into account the methodology for assessing the risk of the impact of drinking water quality on public health in the system of environmental and hygienic monitoring.

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