Arsenic contamination in drinking water from groundwater sources and health risk assessment in the Republic of Dagestan, Russia

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ABSTRACT: In this study the data of arsenic content in groundwater of the Republic of Dagestan are presented. Due to naturally occurring arsenic in the sediments the groundwaters, used by population for drinking, content high level of arsenic compound. The contamination level varied from 1 to 500 $\mu\text{g L}^{-1}$ with an average arsenic concentration of 190 $\mu\text{g L}^{-1}$. 90% of water samples are above the WHO standard of 10 $\mu\text{g L}^{-1}$. The high arsenic concentrations found in the artesian water samples (15.8% above 10 $\mu\text{g L}^{-1}$ and 84.2% above 50 $\mu\text{g L}^{-1}$) indicate that more than 500 thousand of people consuming untreated groundwater might be at a considerable risk of chronic arsenic poisoning. The evaluation of cancer risks from oral exposure to As were found to be above the acceptable U.S.EPA and WHO cancer health risk range of 1×10^{-6} to 1×10^{-4} .

1 INTRODUCTION

Groundwater is a significant source for portable water for millions of people worldwide (Bhattacharya *et al.*, 2006). Naturally occurring groundwater As contamination has been reported in several countries of the world, with concentration levels exceeding the WHO drinking water guideline value of 10 $\mu\text{g L}^{-1}$ (WHO, 2001; 2012).

Previous studies had revealed that groundwater, used by population as drinking water, in some areas of the Dagestan Republic also contained high levels of As (Kurbanova *et al.*, 2013) exposing a significant population to health risk. However, the extent of risk and the extent of As contamination in groundwater sources is unknown. A human health risk assessment exposed to arsenic in drinking water was carried out in this study, in line with US EPA risk assessment guidelines. The aim of this study is to show spatial distribution of As in this region and human health risk assessment of chronic oral exposure.

2 METHODS

2.1 Water collection, arsenic analysis and exposure

703 water samples were collected from the arsenic-contaminated groundwater in the northern districts of Dagestan Republic. During sampling, the plastic containers were rinsed several times with the sample before the final sample was taken. The water samples were acidified by adding 1 mL of 10% analytical grade HNO_3 and brought to the laboratory. Water samples were analyzed for total As by flow-injection hydride generation-atomic absorption spectrophotometry (FI-HG-AAS).

Figure 1. Map of artesian basin with As concentration in different villages of the Dagestan Republic, M 1:500000.

2.2 Human health risk assessment: Calculation of carcinogenic health risk

More than 200 million people in 105 countries around the world are exposed to arsenic at concentrations much higher than the guideline value, and therefore the public health priority should be to reduce exposure for these people. In this study cancer health risk for population was evaluated using human health risk assessment method (WHO, 2010). The exposure route evaluated is oral. According to IARC (1987; 2004), arsenic has been classified as a class 1 human carcinogen, based on sufficient evidence from human epidemiological data that exposure to arsenic causes several forms of cancers. Carcinogenic risks for oral exposure to As were calculated by using following equation:

$$\text{Cancer health risk (CR}_{\text{oral}}) = (\text{ADD}) \times \text{CSF (Eqn. 1)}$$

Table 1. Association between exposed population and As level in drinking water.

Area	The level of arsenic in drinking water, $\mu\text{g L}^{-1}$	Population
1	10–40	167134
2	50–90	16985
3	100–190	108147
4	200–300	9023
5	400–500	8444

where ADD is the average daily dose of As in water via oral exposure route in the study area by population; CSF is the cancer slope factor for oral exposure to As which is $1.5 \text{ mg kg}^{-1} \text{ d}^{-1}$.

3 RESULTS AND DISCUSSION

3.1 Spatial distribution of arsenic in drinking water

The concentration of As in water samples collected in this study ranged from 10 to $500 \mu\text{g L}^{-1}$ with a mean value $190 \mu\text{g L}^{-1}$ (Fig. 1). The observed differences in As concentrations are due to spatial variation in the regional hydrogeochemical parameters which control the mobilization in groundwater (Bhattacharya *et al.*, 2006).

Most of the water samples (97%) contained As at levels higher than WHO MCL value of $10 \mu\text{g L}^{-1}$. 4.8% water samples contained As at the levels 400–500 $\mu\text{g L}^{-1}$. 53.9% of population use drinking water with the level of As 10–40 $\mu\text{g L}^{-1}$. Groundwater with the high concentration of As (400–500 $\mu\text{g L}^{-1}$) used by 3% of the northern districts population. The level of As in the water is detected 20 times or more in 12 villages with the total population of about 16 thousand of people (Table 1).

3.2 Cancer risk results

Cancer health risk is defined as the incremental probability that cancer may develop during life due to chronic As exposure. According to U.S.EPA exposure factors and the International Agency Research on Cancer (IARC), As is the metal among the list of metals that are likely to be carcinogenic via oral ingestion with contaminated water³.

The results of cancer risk for resident adults from the study area exposed to As via oral ingestion of water are presented in Table 2.

In the study area, ADD for oral exposure ranged from $0.0003 \text{ mg kg}^{-1} \text{ d}^{-1}$ to $0.014 \text{ mg kg}^{-1} \text{ d}^{-1}$. It has been shown that the lifetime individual cancer risks were at the minimum As concentration ($10 \mu\text{g L}^{-1}$) – 4.3×10^{-4} ; at maximum As concentration ($500 \mu\text{g L}^{-1}$) – 2.1×10^{-3} , respectively, with a mean of $190 \mu\text{g L}^{-1}$ – 8.1×10^{-3} . The evaluation of cancer risks from exposure to As in this study were found to be above the acceptable U.S.EPA and WHO cancer health risk (1×10^{-6} to 1×10^{-4}) and not permissible for population. The annual cancer health risks

Table 2. Cancer risk for exposed population in the Dagestan Republic.

Level of arsenic in drinking water ($\mu\text{g L}^{-1}$)	Individual cancer health risk
10–40	4.29×10^{-4} – 1.71×10^{-3}
50–90	2.14×10^{-3} – 3.86×10^{-3}
100–190	4.29×10^{-3} – 8.14×10^{-3}
200–300	8.57×10^{-3} – 1.29×10^{-2}
400–500	1.71×10^{-2} – 2.14×10^{-2}

for population were from 1 to 95 additional cases of possible occurrence of cancer.

4 CONCLUSIONS

The results of the water samples analysis revealed high concentrations of As in groundwater, used by population for drinking. 97% of water samples showed As concentration higher than WHO and safe levels. Health risk assessment models indicated that oral exposure to As by consumption of groundwater presented potential carcinogenic risks and the population of the north districts of the Dagestan republic in the study area are at risk of developing cancerous diseases due to As exposure via drinking water. Further research should be directed to case-control epidemiological studies. in the areas of Dagestan with elevated As in groundwater.

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