Preliminary communication

Preliminary investigation of the possible association between arsenic levels in drinking water and suicide mortality

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ABSTRACT

Background: Arsenic-contaminated drinking water (ACDW) represents a major global public health problem. A few previous studies suggested that consuming ACDW may be associated with elevated risk for depression.
Aim: Since depression is the most relevant risk factor for suicide, we hypothesized that consumption of ACDW may be also associated with suicide.
Method: To investigate this, we compared the age-standardized suicide rates (SSR) of 1639 Hungarian settlements with low (≤ 10 μg/l), intermediate (11–30 μg/l), high (31–50 μg/l) and very high (≥ 51 μg/l) levels of arsenic in drinking water.
Result: We found a positive association between SSR and consumption of ACDW.
Limitations: (1) we used aggregated (i.e., non-individual) data; (2) we have not adjusted our model for important medical and socio-demographic determinants of suicidal behavior; (3) we had no data on differences in bottled water consumption between settlements.
Conclusions: Our results indicate that in addition to its well-known adverse health effects, consumption of ACDW may also be associated with suicidal behavior.

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1. Introduction

A considerable part of the global population (e.g., residents of some parts of Argentina, Bangladesh, Chile, China, Hungary, India, Mexico, Taiwan and the USA) is exposed to arsenic-contaminated drinking water which is the main source of inorganic arsenic (As) exposure in humans (Villaescusa and Bollinger, 2008; Brinkel et al., 2009; Dura et al.; Rahman et al., 2009). Around the year 2000 the World Health Organization, the European Union and the USA have set 10 μg As/liter as the highest allowable limit of arsenic in drinking water, but Hungary (joined to the EU in 2004) received a temporary derogation – until December, 2012 – from the European Commission to achieve the above requirement (i.e. decreasing the concentration of As below 10 μg/l) (Villaescusa and Bollinger, 2008).

Arsenic is one of the most toxic elements with deleterious effects on different organs, including the central nervous system (CNS). Accordingly, besides the epidemiological results on the positive association between arsenic exposure and several somatic disorders there are also some findings indicating an association between arsenic exposure and elevated risk for neuropsychiatric disorders, including anxiety and depression (Sen and Sarathi Biswas, 2012; Villaescusa and Bollinger, 2008; Brinkel et al., 2009; Dura et al.; Rahman et al., 2009; Tyler and Allan, 2014; Zierold et al., 2004; Mukherjee et al., 2014). In consonance with the latter finding on depression in humans, perinatal arsenic exposure resulted in a depressive-like phenotype in mice which may be reversed with antidepressant treatment during adulthood (Tyler et al., 2014).

Hungary had tremendously high suicide rates in the last century (the peak of the suicide rate was in the year 1983 (45.9/100,000/year) and suicide rates of the total population were not below 24/100,000/year between 1961 and 2011) (Rihmer et al., 2013). Within-country regional differences in suicide rates are well-known and the spatial pattern of suicides is almost unchanged since its first

decription in 1864 (Rihmer et al., 2013). In addition, it is also known that drinking water is contaminated with arsenic in a significant manner in several parts of the country. For example, at the end of the 1990s approximately 1.4 million inhabitants of the 10.3 million total population consumed water with arsenic concentrations above 10 μg/l (Dura et al., Dura et al., 2004).

Piped drinking water supply is available in a high proportion of dwellings in Hungary (92% in 2000 and above 95% in 2011) (Központi Statisztikai Hivatal, 2012).

Taken together that some findings suggest that arsenic exposition is associated with depression and that depression is the main known risk factor for suicide, we hypothesized that consumption of arsenic-contaminated drinking water may be associated with elevated suicide risk as well (Sen and Sarathi Biswas, 2012; Tyler and Allan, 2014; Zierold et al., 2004; Rihmer et al., 2013; Mukherjee et al., 2014).

2. Method

In order to handle the problem that suicide is a relatively rare event (1) we investigated our hypothesis in a relatively long 7-year period (between 2005 and 2011) and (2) excluded settlements with a population less than 500 (in the year 2005) from our calculations ($n=1039$). (This exclusion was also supported by the supposition that in these small villages a bigger proportion of drinking water may be derived from private wells instead of piped water supply). Our raw data on numbers of annual suicide cases and population for all Hungarian settlements were provided by the Hungarian Central Statistical Office. First – in cases of every given settlement – an average annual suicide number was calculated from the suicide cases of the 7-year period investigated. Secondly, we calculated an average number of population from the seven annual population numbers for every given settlement. Then, by taking the age composition of the European Standard Population as a standard, we calculated age-standardized suicide rates (/year/100,000 inhabitants; SSR) for every settlement using the direct method.

Our four-level variable on arsenic contamination in piped drinking water was provided by the National Institute of Environmental Health, Budapest, Hungary. If more than one arsenic levels were reported to the National Drinking Water Database from the same year for the same settlement then the average of these was used to establish the level of our variable for that year. Monitoring frequency varies between water supplies, thus we excluded settlements without at least one annual arsenic data for the period between 2005 and 2011. Settlements were classified into four groups based on their level of arsenic contamination in drinking water (i.e., low ($10 \,\mu g/l \geq As$); intermediate ($As = 11–30 \,\mu g/l$); high ($As = 31–50 \,\mu g/l$) and very high ($51 \,\mu g/l \leq As$) levels). If a settlement had more than one annual arsenic data for the period investigated the highest one from these was taken into consideration when the given settlement was classified into one of the four categories mentioned above.

After all exclusions 1639 settlements remained from the whole group of Hungarian settlements ($n=3145$).

Data were checked with Levene's test for homogeneity of variances. We examined using one-way analysis of variance (ANOVA) whether there was a statistically significant effect of arsenic contamination on SSR. For post-hoc analysis Student's t-test with Bonferroni's correction was applied to compare mean SSRs pairwise. Data were managed using SPSS, version 19 (SPSS, Inc. Chicago, Illinois).

3. Results

Table 1 shows the descriptive data (e.g., SSRs; average population sizes) of the four settlement groups with different levels of arsenic contamination in their piped drinking water.

The variances of the four groups were homogenous (Levene's test: $p=0.91$).

The means of SSRs were higher for those settlements where the levels of arsenic contamination were also higher (Table 1; ANOVA: $F=16.83$; $p < 0.001$; $df=3$). According to the results of the post-hoc test these differences were statistically significant only in comparisons between group II. (intermediate) and group I. (low) and between group III. (high) and group I. (low) ($p < 0.001$ for both cases) but not between group IV. (very high) vs. group I. (low) ($p=0.187$). Average population sizes of settlements were broadly similar in the four groups (Table 1).

4. Discussion

According to our knowledge this is the first report on the possible association between arsenic contamination in drinking water and suicide rate. Our results indicate that there is a positive association between the two variables investigated. This is of particular interest since – in spite of the continuous decline of the Hungarian suicide rate in the last 30 years – the spatial pattern of regional suicide rates within Hungary has been quite stable over time and this phenomenon still lacks a satisfactory explanation (Rihmer et al., 2013). Mean population number of settlements were broadly similar in the four groups (Table 1). Therefore, it is unlikely that our results would be explained by the well-known fact that suicide rates are higher for rural than urban areas (Rihmer et al., 2013).

It is well-known that depression is the main risk factor for suicidal behavior (Rihmer et al., 2013). Results of some epidemiological studies indicated that the consumption of arsenic-contaminated drinking water may lead to various psychiatric disorders, including anxiety and depression (Sen and Sarathi Biswas, 2012; Tyler and Allan, 2014; Mukherjee et al., 2014). On the other hand, findings of animal studies on the depressogenic effects of perinatal arsenic exposure may also give credence to our finding (Tyler et al., 2014).

There are some limitations to this preliminary study: (1) we used aggregated (i.e., non-individual) data so our results and conclusions are not inevitably true on the level of individuals; (2) we have not

Table 1
Descriptive data of groups of settlements with different levels of arsenic contamination.

Group of settlements	As level	Number of settlements in the group	Average population of settlements in the group (mean)	Standardized suicide rates		
				Mean	Standard deviation	95% confidence interval
I.	$10 \,\mu g/l \geq As$	1249	5871	23.6	18.4	22.6　24.6
II.	$11–30 \,\mu g/l$	289	5017	30.6	17.2	28.6　32.6
III.	$31–50 \,\mu g/l$	86	3066	32.0	17.7	28.2　35.8
IV.	$51 \,\mu g/l \leq As$	15	4373	33.8	21.4	21.9　45.6

adjusted our model for important medical and socio-demographic determinants of suicidal behavior; (3) we had no data on differences in bottled water consumption between settlements.

Since this is the first preliminary report on the possible association between arsenic intake from drinking water and suicidal behavior our results need confirmations by studies preferably with prospective design and based on individual-level arsenic data. Such studies would be also able to decide whether there is a causal link behind the association found by us.

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