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THE INTAKE OF NICKEL, CADMIUM AND MANGANESE THROUGH THE INGESTION OF GROUNDWATER FROM SEVERAL PRIVATE WELLS FROM BAIA MARE (ROMANIA) METROPOLITAN AREA

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ABSTRACT. There is a strong relationship between drinking water contamination with heavy metals like Pb, Cd, Cu, Mo, Ni, or Cr and chronic diseases such as renal failure, liver cirrhosis, hair loss, and chronic anaemia. The present study evaluates the content of nickel, cadmium and manganese in thirteen private wells from four rural areas located in Baia Mare (NW Romania) metropolitan area. Based on the Ni, Cd and Mn concentration, the heavy metals daily intake rates were calculated for the female, male and children who use these water sources as drinking water supplies. The daily ingestion rate of Ni, due to water consumption, was considerably higher for the inhabitants from Tăuţii de Sus (0.38 – 0.96 µg/day/person), while the Cd (0.04 – 0.11 µg/day/person) and Mn (0.53 – 0.98 µg/day/person) ingestion was higher for the inhabitants from Bozânta Mare and Bozânta Mică villages.

Key words: *daily ingestion rate, drinking water, heavy metals*

INTRODUCTION

Drinking water contamination is directly related to the population health. Due to the well-known toxicity and low biodegradation, as well as the threat to the environment and public health, heavy metals have been widely studied in various environmental and biological compartments (Antonie, 2014; Culea et al., 2014), (Neagu et al., 2010). Ingestion of drinking water, vegetables and fruits contaminated with heavy metals represent the main ways in which these elements enter the human body. Once entered into the body, some heavy metals like Pb, Cd, Cu, Mo, Ni, or Cr can lead to chronic diseases such as renal failure, liver cirrhosis, hair loss, and chronic anaemia.

The main anthropic sources of heavy metals in environment are the mining and smelting activities. The present study was conducted in Baia Mare area, one of the important mining areas from Romania. The mining of gold-silver, lead-zinc and

copper ore deposits has been the main economic activity for many centuries, but its decline after 1990 created serious economic, social and environmental problems. The soil in Baia Mare mining area is contaminated especially with lead, copper, zinc and cadmium, as a consequence of the pollutants emission and dispersion during the mining and post-mining activities, as well as the ore processing industry or improper tailings storage (Big et al., 2012; Cordos et al., 2007; Damian et al., 2008[a,b]; Frentiu et al., 2009; Lăcătuşu et al., 2002). There are few recent data (Bird et al., 2009; Gurzău et al., 2012) regarding the presence of heavy metals in drinking water from the wells in the area of Baia Mare. The main objectives of the present study were: (1) to investigate the presence of Ni, Cd and Mn in thirteen private wells located in Baia Mare area, and (2) to evaluate the possible health effects to the residents caused by Ni, Cd and Mn uptake via water ingestion, by calculating the daily intake rates.

MATERIALS AND METHODS

The drinking water samples were collected from thirteen private wells, located in four villages from Baia Mare metropolitan area (Tăuții de Sus, Satu Nou de Sus, Bozânta Mare and Bozânta Mică) (figure1). The samples were collected in July 2014.

Fig. 1. *The location of the sampling points (Source: Google earth).*

The water samples were sampled in polyethylene bottles, filtered (0.45 μm) and acidified to a pH ≈ 2 (with HNO_3 65%). They were stored at dark and at cold (4ºC) and analysed within 48 hours from sampling. The lead content was analysed in the laboratory by Atomic Absorption Spectrometry (AAS, ZEENIT 700 Analytik Jena).

The potential chronic risks associated with the exposure to Ni, Cd and Mn by water consumption were evaluated by calculating the daily intake rate (DIR) (µg/day) using the following formula (Li et al., 2014):

$$DIR = \frac{C \times I_R}{BW}$$

where, C is the heavy metal concentration in water sample (mg/l); IR is the water ingestion rate (l/person/day); and BW is the average adult / child body weight (kg).

A questionnaire-based survey was performed during the water sampling. The questionnaire acquired the basic information regarding water ingestion rate, number of family members, their age, and average weight.

RESULTS AND DISCUSSIONS

The analysed water samples proved to have a high content of heavy metals (figure 2).

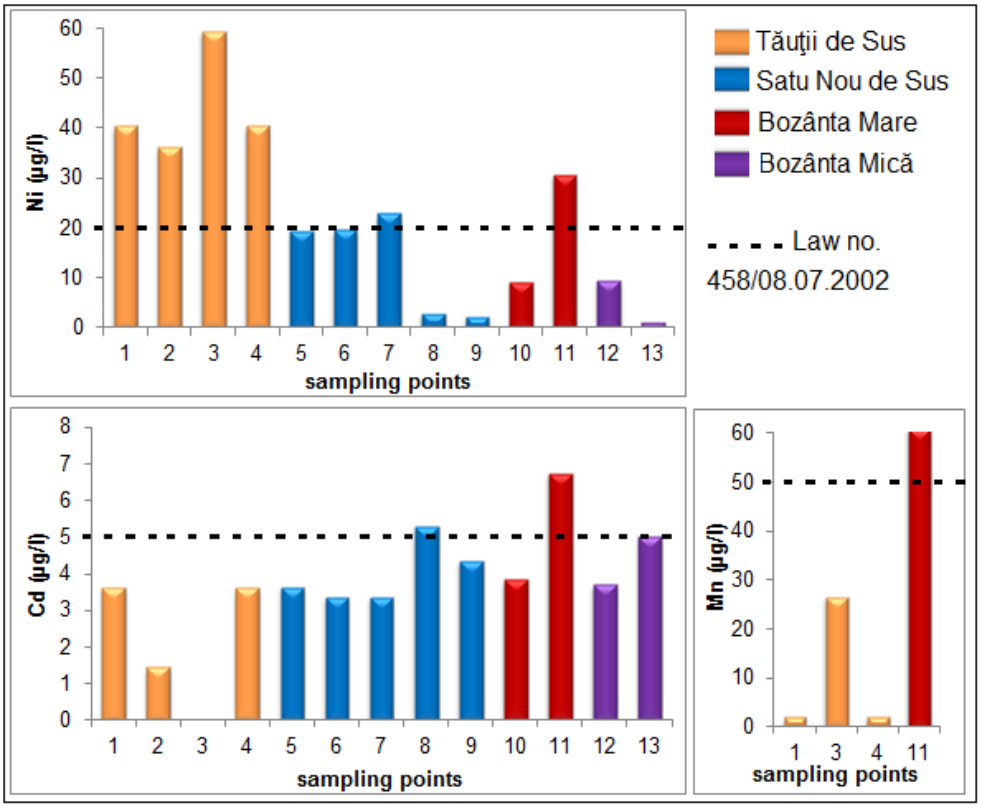

Fig. 2. *The content of Ni, Cd and Mn in the analysed water samples, comparing to the maximum level set by national legislation for drinking waters.*

The Ni content of the analysed private wells ranged between 1.1 and 59.4 µg/l, being higher in Tăuţii de Sus village than in the other villages. The Ni content exceeded the maximum permissible limit (MPL) (20 µg/l) imposed by national legislation for drinking water (Law no. 458/08.07.2002) in 46% of the analysed wells. The high level of Ni is the consequence of the wells location in the close vicinity of Tăuţii de Sus tailing pond. Nickel can infiltrate from the tailing pond into phreatic water leading to ground water contamination.

The presence of such high levels of Ni in the drinking water represents a high risk for human health considering that nickel is found on the International Agency for Research on Cancer (IARC) list of dangerous pollutants for human health, being classified as Group 2B - substances which are possibly carcinogenic to humans (IARC, 2016).

In the case of Cd and Mn, the highest levels were registered in the wells from Bozânta Mare village. Cadmium ranged between 1.4 – 6.7 µg/l, exceeding the MPL (5 µg/l) in two samples (8 and 11) (figure 2). The presence of such high levels of Cd in the drinking water represents a high risk for human health considering that cadmium is found on the International Agency for Research on Cancer (IARC) list of dangerous pollutants for human health, being classified as Group 1 - substances which are human carcinogen (IARC, 2016). The inhabitants who use the wells 8 and 11 as constant sources of drinking water may have severe kidney and liver disease. Both kidney and liver act as cadmium stores; 50–85% of the cadmium intake is stored in kidney and liver (WHO, 2011). Considering the high biological half-life of cadmium in humans (in the range 10–35 years), only a small part of the absorbed cadmium will be excreted in the urine. It is estimated that about 0.007% of the body burden is excreted daily by adults, but individual variation is large (WHO, 2011).

Manganese was detected in 31% of the analysed wells, which are located in Tăuţii de Sus and Bozânta Mare villages. Only in the sample no. 11 (Bozânta Mare) the Mn level exceeded the MPL (50 µg/l) set by national legislation. The high Cd and Mn levels from wells 11 – 13 is a consequence of wells location in the close vicinity of the tailings ponds Remin, Aurul and Sasar located in the area.

The daily intake rate (µg/day per kg body weight) was estimated based on the daily consumption rates of water from the investigated wells and the Ni, Cd and Mn concentrations in water samples.

A questionnaire-based survey was performed on 50 residents, out of which:

- 12% were children (between 3 and 13 years old). The average weight was 75 kg for males (ranging between 56 and 88 kg), 67 kg for females (ranging between 53 and 84 kg), and 34 kg for children (ranging between 12 and 45 kg).
- 46% were females (12% from 18 to 29 years old, 35% from 30 to 49 years old, and 53% from 50 to 78 years old),
- 42% were males (17% from 18 to 29 years old, 28% from 30 to 49 years old, and 55% from 50 to 73 years old),

Based on the questionnaire information, the average intake of water from the monetarised wells was 0.8 l for adults, both female and male and 0.55 l for children.

The estimated daily intake rates (µg/day per kg body weight) of Ni, Cd and Mn caused by water ingestion are presented in figure 3. The present study proved the high contribution of water ingestion to Ni intake, for the inhabitants from Tăuţii de Sus village

(0.38 – 0.96 µg/day per kg body weight) comparing to Satu Nou de Sus village (0.02 – 0.37 µg/day per kg body weight) and Bozânta Mare and Bozânta Mică villages (0.01 – 0.49 µg/day per kg body weight).

The tolerable daily intake for Ni is 11 µg/day/kg body weight, value which was recommended by World Health Organization (WHO, 2007). The Ni intake caused by water ingestion from the investigated wells, represents a percentage of 0.1 – 8.7 % from the tolerable daily intake for Ni.

The scenario is different in the case of Cd and Mn, where the contribution of water ingestion to Cd and Mn intake was lower for the inhabitants from Tăuţii de Sus village (0.01 – 0.058 µg/day per kg body weight for Cd and 0.02 – 0.42 µg/day per kg body weight for Mn) comparing to Bozânta Mare and Bozânta Mică villages (0.04 – 0.11 µg/day per kg body weight for Cd and 0.53 – 0.98 µg/day per kg body weight for Mn).

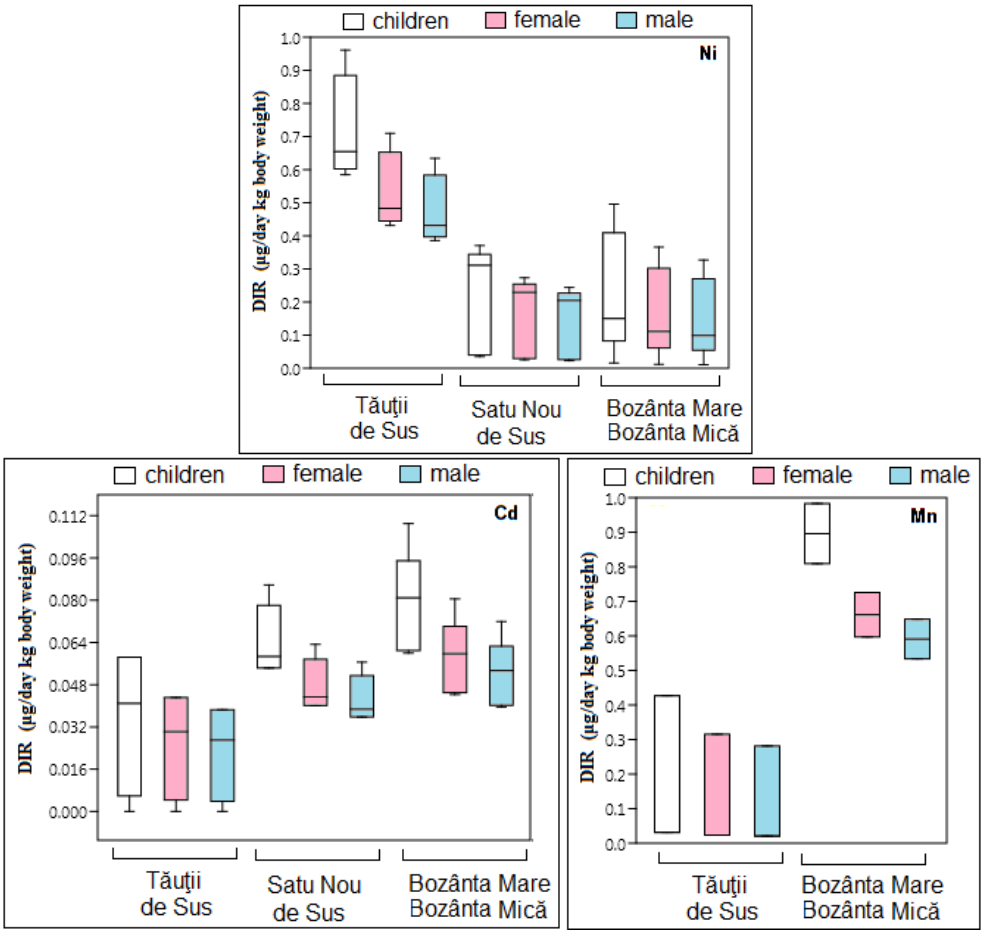

Fig. 3. *The estimated daily intake rate (DIR) (µg/day per kg body weight) of Ni, Cd and Mn via water ingestion.*

The tolerable daily intake for Cd is 1 µg/day kg body weight, value set by FAO-WHO (2001). The Cd intake caused by water ingestion from the private wells, represents a percentage of 1 – 11% from the tolerable daily intake for Cd.

The tolerable daily intake for Mn is 0.06 mg/kg body weight, set by WHO (2011). The Mn intake caused by water ingestion from the investigated wells, is considerably lower than in the case of Cd and Ni, being lower than 0.002% from the tolerable daily intake for Mn.

The results showed that the DIR was higher for female than for male. The DIR was reported as µg of heavy metal daily ingested by a person per kg body weight, as a consequence due to the lower body weight of female the DIR was higher. For all the investigated villages, the DIR was higher for children than for adults, because in their case the ingested dose was reported to a lower body weight.

The continuous usage of private wells from Tăuţii de Sus and Bozânta Mare villages, as drinking water supplies represents a high risk for the inhabitants' health, especially for their children. As a consequence, in order to decrease the heavy metal intake, the inhabitants from these villages should stop or reduce the use of private wells as drinking water supply. These water sources must be carefully monetarised because even at low levels, the presence of Cd and Ni may cause a range of health effects.

CONCLUSIONS

The analysed wells proved to have high content of Ni, Cd and Mn, exceeding the maximum permissible limits imposed by national legislation for drinking water in a total of 46%, 15% and 8% of the analysed wells.

The highest levels of Ni were detected in Tăuţii de Sus village, located in the close vicinity of the tailing pond, while the highest levels of Cd and Mn were detected in Bozânta Mare village, located in the close vicinity of tailing ponds.

The Cd and Ni intake caused by water ingestion from the private wells, represents a percentage of 1 – 11% and 0.1 – 8.7% from the tolerable daily intake for Cd and Ni, while in the case of Mn, the intake is lower than 0.002% from the tolerable daily intake for Mn.

Because of the high level of Ni, Cd and Mn, the usage of some of the private wells from Tăuţii de Sus and Bozânta Mare villages, as drinking water supplies should be considerably restricted, because is a real threat for residents health.

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