Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2022.28437

259 (2022) 133–151
May

Minerals in tap water and bottled waters and their impact on human health

Ewa Wysowska[a,*], Iwona Wiewiórska[b], Alicja Kicińska[c]

[a]*Sądeckie Wodociągi Spółka z o.o. w Nowym Sączu/AGH University of Science and Technology, Poland, email: ewa.wysowska@swns.pl*
[b]*Sądeckie Wodociągi Spółka z o.o. w Nowym Sączu, Poland, email: iwona.wiewiorska@swns.pl ORCID: 0000-0002-6360-7702*
[c]*Department of Environmental Protection, Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology, Mickiewicza 30 av., 30-059 Kraków, Poland, email: kicinska@agh.edu.pl, ORCID: 0000-0003-2725-7319*

Received 21 February 2022; Accepted 27 March 2022

ABSTRACT

The aim of the study was to determine the doses of selected bioelements delivered to the body as a result of consuming water from various types of intakes (surface water from the river, water from infiltration wells, treated water directed to the water supply system) and additionally as a result of using bottled water. The present study analysed the content of 33 elements in water, grouped into microelements, ultratrace elements and other elements found in the aquatic environment. The majority of those elements are essential to proper human development and functioning. They can enter the human body together with water: (a) ingested directly, (b) present in food, (c) inhaled or (d) absorbed through skin. The results obtained were compared with the chemical composition of 29 types of bottled water (mineral and spring water) available in the retail market. Reference doses for each of the parameters were calculated in accordance with the US EPA guidelines and compared with the doses recommended in other research studies. Two water treatment plants (WTPs and WTPss) located in southern Poland were selected as research facilities. Water treatment plants treat surface water from rivers and groundwater from infiltration wells using sand filters. It was found that the average mineralisation of water supplied in the water distribution system ranges from 0.15 to 0.2 mg dm^{-3}, which indicates that it has characteristics of natural low-mineral spring water. It provides 0.0001%–0.0003% of the recommended daily intake (RDI) for Al, As, Cd, Co, Cr, Cu, Mn, Mo, Ni, P, and Sn for children and for adults. The novelty of the article is the determination of the doses of microelements in bottled water. Bottled mineral water provides considerably higher doses of microelements than the values stemming from the RDI. The delivered doses of carcinogenic and potentially carcinogenic elements are of particular importance. In the case of Al, Cr, and Ni, the total recommended dose was exceeded 1 to 2 times for children and 1.5–7 times for adults. It was demonstrated that consumers should be careful about drinking water with an elevated content of microelements that are characterized by a very small, yet critical difference between the reference dose and the recommended dose.

Keywords: Bottled water; Health safety; Microelements and ultratrace elements; Tap water

1. Introduction

In order to develop and function properly, people require an adequate amount of high-quality water containing dissolved nutrients and vitamins. Water comprises about 60%–70% body weight in adults and is a medium participating in homeostatic cell transformation. The quantitative demand for water varies between individuals and depends on the climate, diet, physical activity, sex, and age. Hydration requirements change over the course of human

* Corresponding author.

Presented at the 2nd International Conference on Critical Infrastrcture of Cities (CIC 2021), 6–8 October 2021, Rytro, Poland

1944-3994/1944-3986

life and are the highest in infants [1]. During the first four months of life, the demand for water is four times higher than in adulthood, amounting to 100–190 mL kg^{-1} b.w. d^{-1} [2]. Children under the age of 2 should consume 1.1–1.2 dm^3 d^{-1} of water. The demand for water decreases with age but remains at about 2 dm^3 d^{-1} for men and about 2.5 dm^3 d^{-1} for women. Additionally, during pregnancy and lactation water intake should be increased by about 0.3 and 0.7 dm^3 d^{-1}, respectively [3,4].

Recommendations regarding water quality vary depending on the consumer group concerned. The strictest requirements apply to water intended to be consumed by children [5]. In the case of healthy small children (up to the age of 6), it is recommended to only give them boiled water or bottled spring water that meets specific quality criteria, especially regarding the content of microelements and ultratrace elements, for example, Mn and potentially toxic elements [6,7]. In the period of introducing new foods to infants, the recommended supplementing liquid (in addition to breast milk) is low-mineral water or spring water approved for this purpose by sanitary and epidemiological authorities [8]. However, there are certain social groups who question the idea of giving children tap water to drink and using it to prepare meals [9,10].

The main applicable normative act regulating the quality of water for human consumption provided through public water distribution systems in the EU is the Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption [11]. This document is the answer to the changing environmental conditions and new types of pollutants present in water. The directive includes, for example, for example, updated standards for physicochemical and microbiological parameters of water intended for human consumption and, most importantly, imposes an obligation on water distribution companies in the EU to monitor these parameters in their distribution systems. The document emphasizes the need to provide safety of water consumption throughout the entire lives of its recipients and focuses on the presence of biogenic elements in water. Natural mineral waters and medicinal waters are excluded from the scope of this directive. These types of water are subject to control based on Directives 2009/54/EC [12] and 2001/83/EC [13]. Roșca et al. [14] investigated potential metal and metalloid contamination and assessed the health risk of glacial waters from the Rodna Mountains in Romania. The following parameters were used to determine the potential contamination and health risk: heavy metal pollution index – HPI, heavy metal evaluation index – HEI and the degree of contamination – C_d. The metal pollution indices indicated that the water samples presented no metal pollution. The values ranged from 5.17 to 27.84 for HPI, 0.55 to 5.07 for HEI, and –8.45 to –3.93 for C_d. The water quality index (WQI) indicated excellent and good quality of the tested samples, with an average score of 22.6 and a range of 11.4 to 46.9. Dippong et al. [15] assessed the quality of surface water in the Strîmtori-Firiza reservoir by analysing 14 physicochemical parameters among 9 metals in 18 sampling sites. A series of potential reservoir pollutants were identified, depending on the nature of the pollutants.

1.2. Mineral elements in water

Substances dissolved in water play an important role, as they have a considerable impact on the proper functioning of the human body. Based on the human demand for these substances, the following groups can be distinguished:

- macroelements (comprising up to 90% of substances dissolved in water; their content in the human body is higher than 0.01% by mass), including: HCO_3^-, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, K^+, and Na^+;
- microelements and secondary elements (their content in human body is <0.01%), including: N, Fe, Si, Zn, Cu, F, Cr, Mn, Mo, B, Co, Ni, Sn, and W;
- ultratrace elements (their content in human body is <0.00001%), including: Au, Ag, and Ra.

As indicated by the WHO, people require both macroelements and trace elements to function properly [16]. Mineral water is characterized by a high content of both these types of elements. Between 90% and 99% of its chemical composition are anions: bicarbonate (HCO_3^-), sulphate (SO_4^{2-}), chloride (Cl^-), and cations: sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}). Microelements found in bottled mineral water usually do not comprise more than 1% of its chemical composition [17]. However, from the medical standpoint, not every mineral water should be consumed on a daily basis. A mineral element found in water may have a beneficial impact on human health if its content is not lower than 15% of the daily demand [18]. The majority of microelements and specific elements are metals. Thus, additional care is required as they become toxic in high concentrations [6,19]. Nevertheless, their presence is not only permissible (in concentrations regulated by appropriate standards) but also beneficial, especially in mineral and medicinal waters (e.g., Ca, Mg, Cr or Cu) [20,21].

The assessment of health and toxicological risk for humans related to using different types of water is mostly focused on detecting pollutants. In recent years, societies have become increasingly aware of the possibility to drink water directly from the water distribution system. However, in some countries this approach is discouraged through actions promoting the consumption of solely "demineralised" water, filtered at the household, or bottled water. Water from public water distribution systems usually has the properties of low-mineral spring water. The treatment process removes harmful microbiological pathogens, while at the same time preserves the micro- and macroelements required for the proper functioning of the human body in permissible concentrations.

The purpose of this study was to identify and discuss the nutrients present in tap water, which are essential for the proper development and good health of its consumers. Based on the tests of raw water and water directed to the water distribution system, as well as the analysis of physicochemical parameters listed on the bottled water labels:

- the content of selected bioelements was determined in water;

- the differences in the concentrations of individual elements were identified and discussed;
- the doses of selected bioelements consumed through bottled water and water from the distribution system were determined;
- the compliance of the ingested doses with the WHO recommendations was verified.

2. Materials and methods

The study material comprised water samples collected over 12 months in monthly cycles from water intakes supplying the Stary Sącz Water Treatment Plant (WTPss) and the Świniarsko Water Treatment Plant (WTPs). Both plants are located in southern Poland (EU, Małopolskie Province) and treat surface water of the Dunajec River (WTPs and WTPss) and water from infiltration wells (11 infiltration wells and 16 infiltration wells for WTPs and 16 infiltration wells for WTPss). WTPs and WTPss use a high-efficiency water treatment system, including rapid filtration in filters with an anthracite-sand bed and final disinfection with UV rays and gas chlorine.

Due to the restrictions and other difficulties related to the SARS-Cov-2 pandemic, samples were not collected in April 2020.

Physicochemical properties were analysed for: (1) raw water, (2) water treated in sand filters and (3) water directed to the municipal water distribution system.

The samples for WTPs were taken from (Fig. 1, points i–vi):

(i) Water treated at WTPs and supplied to the distribution system;
(ii) Water treated at WTPs and supplied to the distribution system 2 d after sampling described in (i);
(iii) Water from 16 infiltration wells located in Świniarsko, supplying WTPs;
(iv) Water from a surface water intake on the Dunajec River in Świniarsko, supplying WTPs;
(v) Water treated in sand filters at WTPs;

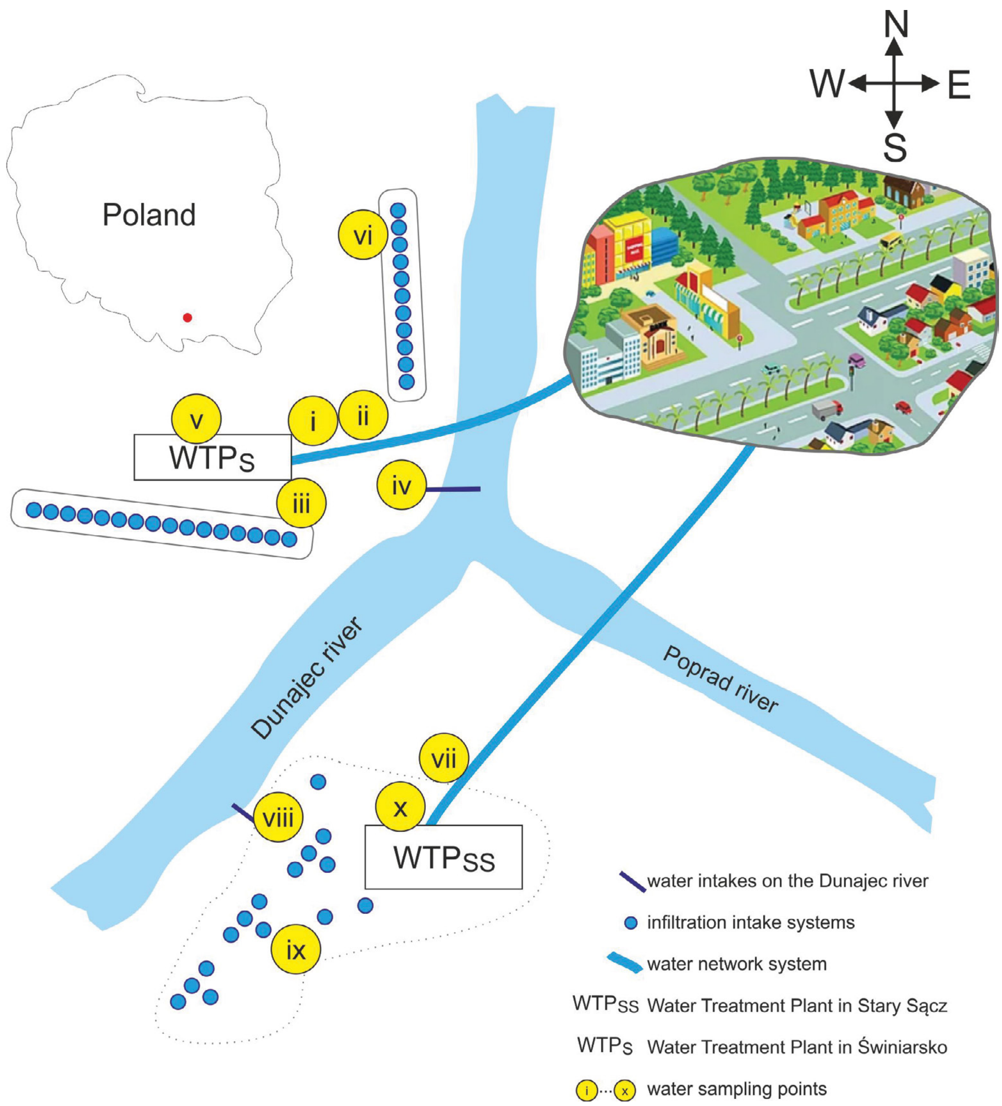


Fig. 1. Location of water sampling points.

(vi) Water from 11 infiltration wells located in Mała Wieś, supplying WTPs;

The samples for WTPss were taken from (Fig. 1, points vii–x):

(vii) Water treated at WTPss and supplied to the distribution system;
(viii) Water from a surface water intake on the Dunajec River in Stary Sącz, supplying WTPss;
(ix) Water from 16 infiltration wells located in Stary Sącz, supplying WTPss;
(x) Water pre-treated in sand filters at WTPss.

A total of 102 water samples were taken in the period between December 2019 and December 2020. They were analysed to determine the content of 33 bioelements divided into the following groups:

- 17 microelements: B, Ba, Cu, Li, Mn, P, As, Co, Cr, I, Mo, Ni, Rb, Sb, Se, Sn, V;
- 3 ultratrace elements: Ag, Bi, W;
- 13 other elements: Al, Pb, Be, Cd, Cs, Ga, Hg, Te, Ti, Tl, U, Zr, Y.

Among the elements analysed, the following categories were distinguished: 7 elements considered essential for humans: Cu, I, Mn, Mo, Co, Se, Cr; 7 elements considered possibly essential: Ni, Sn, V; as well as 9 elements currently considered non-essential: Al, B, Cd, Sb, Bi, Pb, Hg, Ag, Ti.

Among the total of 102 samples, 63 were taken at WTPs and 39 at WTPss. In total, 2702 parameters were analysed, with 1672 measurements performed for WTPs and 1030 for WTPss. The difference in the number of measurements between WTPs and WTPss stems from the fact that the former is supplied from two water intakes with infiltration wells, while the latter has one water intake with infiltration wells.

Additionally, when analysing the technological processes used for water intake and treatment in the two plants, it was decided to collect samples of water treated at WTPs twice each month within two consecutive days – samples (i) and (ii), Fig. 1. This decision stemmed from the fact that WTPs was supplied with varying quantities of water from different types of intakes. On the first day of sampling, 64% of water was supplied to WTPs from 16 infiltration wells located in Świniarsko, 30% from the Dunajec River and 6% from 11 wells in Mała Wieś. On the second day, the proportions of the water supplied were as follows: 26% from 16 infiltration wells located in Świniarsko, 29% from the Dunajec River and 45% from 11 wells in Mała Wieś. The adopted proportions of water mixed from individual intakes were typical proportions used in the regular operation of the technological system. The percentages of water from individual intakes provided in the paper were actual values read out from the measurements. Water supplied from different intakes is mixed at WTPs to obtain the required water hardness. The main source of water for the two WTP is the Dunajec. It is a mountain river, whose water is characterized by a considerable variation of the physicochemical parameters. This particularly pertains to turbidity, which ranges from 0.01 to several thousand NTU (nephelometric turbidity units). The turbidity level is the main determinant of the water treatment technology to be employed [6,22]. In order to achieve the required quality of water supplied to the public water distribution system, water from the infiltration wells is added to surface water. However, raw water from the 11 wells at Mała Wieś presents a very high level of hardness (reaching several hundred mg dm^{-3}). Therefore, it is mixed in the technological process with water from the river and water from the 16 wells located in Świniarsko (item (iii), Fig. 1) to achieve the required taste.

The element concentrations were determined using inductively coupled plasma mass spectrometry (ICP-MS) at an accredited Hydro-Geo-Chemistry Laboratory at the AGH University of Science and Technology in Kraków (certificate no. AB1050) with an accuracy of 10^{-5}–10^{-6} mg dm^{-3}, at 95% confidence interval ($p = 0.05$).

2.1. Health risk assessment

The health risk assessment procedure involved calculating doses of the tested substances ingested by children and adults through the regular consumption of water supplied from the water distribution system and through the consumption of bottled water (mineral and spring water).

The calculation of the chronic daily intake (CDI) was performed taking into consideration the consumption of water with the assigned parameters throughout human lifetime based on the US EPA [23,24] guidelines. The CDI values were calculated using formula no. 1:

$$\mathrm{CDI} = \frac{\mathrm{CW} \times \mathrm{EF} \times \mathrm{ED} \times \mathrm{IR}_o}{\mathrm{BW} \times \mathrm{AT}} \left[\mathrm{mg} \cdot \mathrm{kg}^{-1}\ \mathrm{bw}\ \mathrm{d}^{-1}\right] \quad (1)$$

where CDI – chronic daily intake (mg kg^{-1} bw d^{-1}), CW – concentration of substance in water (mg dm^{-3}), EF – exposure frequency (d y^{-1}), assumed at EF = 365 [23], ED – exposure duration (y), ED = 26 in adults and ED = 6 in children, IR_o – daily water ingestion rate (dm^3 d^{-1}), IR_o = 2.5 in adults, IR_o = 0.78 in children, BW – body weight (kg), BW = 70 kg in adults and BW = 20 kg in children [24], AT – average exposure time (d), AT = 25550 for children and adults for carcinogenic substances (Al, As, Cd, Cr, Ni according to [25]); the average exposure time of 70 y was assumed due to the carcinogenic and potentially carcinogenic chemicals analysed; AT = 2190 for children and 8,760 for adults for non-carcinogenic substances (B, Ba, Bi, Cu, Ga, Li, P, Mn and Sn).

This method is widely used in research studies [26], especially those related to the assessment of health risk associated with the consumption of water with specified physicochemical parameters US EPA [27,28]. Therefore, the authors of the present study decided to use it for the assessment of the microelement doses ingested. The results obtained were compared with recommended daily intake (RDI) values specified by Kicińska et al. [29].

The results were also compared with quality parameters determined for bottled mineral water and spring water available in the EU market. For this purpose, 29 most popular brands of bottled water available in stores were selected and divided into groups based on the following physicochemical parameters:

- high-mineral water (containing >1,500 mg dm^{-3} of minerals);
- medium-mineral water (containing 500–1,500 mg dm^{-3} of minerals);
- low-mineral water (containing <500 mg dm^{-3} of minerals);
- medicinal water (containing specific elements/compounds providing beneficial health effects).

Data on the concentration of 17 elements: Al, As, Ba, Br, Co, Cr, Cu, Ge, I, Mn, Ni, P, Rb, Se, Sr, Ti, and Zn were collected from the available resources (labels, water manufacturer websites). The lower number of the elements analysed stemmed from the limited availability of information about the contents of individual microelements and ultratrace elements in bottled water. Usually, manufacturers provide information only on the major ions or specific medicinal components. It is also worth noting that the analyses of chemical composition of bottled water performed within the present study were based on a single measurement, not on a series of cyclical laboratory tests.

3. Results

3.1. Bioelements in water from different types of intakes

First, the concentration of individual elements in water samples taken from various locations in the water distribution system was determined. Then, the main statistical parameters were calculated. This allowed for establishing which of the intakes exhibited the highest content of the microelements and ultratrace elements analysed (Tables 1a–c).

The most prevalent elements in all water intakes were: Ba (the share of this element in the total amount of the elements dissolved in water ranged from 20% to 59%), B (4%–30%), Bi (2%–7%), P (1%–30%) and Al (1%–29%). Furthermore, considerable concentrations were observed for: Mn (0.1%–15%), Cu (0.6%–2%), Li (1%–5%) and Ga (0.7%–1.5%). When summed up, these elements made up 95%–98% of all the elements dissolved in water (Table 2).

The analysis of statistically significant element concentrations at different water sampling sites indicated that the highest parametric values of Ba were found in the water treated in sand filters at WTPs (stage (v), Fig. 1) and in the water from the wells in Mała Wieś (vi) – 0.283 and 0.270 mg dm^{-3}, respectively. This association also was found for B (0.178 mg dm^{-3} at stage (v) and 0.106 mg dm^{-3} at stage (vi). The highest concentration of Al was found in the water treated in sand filters at WTPs (stage v) – 0.100 mg dm^{-3} – and in the water taken directly from the Dunajec River in Stary Sącz (stage viii) – 0.092 mg dm^{-3}. Water collected at stage viii was also the main source of Mn (0.045 mg dm^{-3}) and P (0.084 mg dm^{-3}). Average element concentrations determined for each sampling site are presented in Fig. 2.

3.1.1. Water from surface intakes on the Dunajec River (stages iv and viii)

Surface intakes (stages iv and viii, Fig. 1) are located on the Dunajec River, 3.4 km away from each other and are characterised by similar element concentrations. Elements with the highest concentration in raw (untreated) water taken from the Dunajec River at WTPs (stage iv) were: Al, Ba, P, Mn, B, Bi and Li. They comprised 95% of the total quantity (concentration) of the elements dissolved. At the same time, Al, P, Ba, Mn, B and Bi were most prevalent in raw water taken from the same river but at the other intake, in Stary Sącz (stage viii). As for raw water taken from the wells (stages iii, vi, ix), these elements constituted 95% of mineral salts (and >96% in the case of stage ix). When comparing the total concentration of microelements and ultratrace elements determined for water from the surface intakes, it was found that the amount of the dissolved elements was about 13% higher in the samples from the Świniarsko WTP. The total element concentration determined for water taken from the Dunajec River in Świniarsko (stage iv) amounted to: maximum 9.30E-01 mg dm^{-3}, average 2.61E-01 mg dm^{-3}, with the coefficient of variation (CV) of 6.94%. These parameters were considerably higher relative to the river water samples taken at the other intake, in Stary Sącz (stage viii). The total content of the minerals dissolved in water amounted to: maximum 8.08E-01 mg dm^{-3}, average 3.20E-01 mg dm^{-3}, with the CV of 6.62%. It is worth noting that the Świniarsko water intake (stage iv) is located upstream of the Stary Sącz water intake (stage viii). Furthermore, the river carries water originating from the Slovakian river Poprad crossing the Polish border. However, the water quality at this intake was not found to be inferior.

3.1.2. Water from infiltration intakes (stages iii, vi and ix)

The level of well water mineralisation differed at individual intakes (Fig. 2). The highest concentration of elements was found in water from the Mała Wieś intake (stage vi), amounting to an average of 4.61E-01 mg dm^{-3} (maximum 2.61E+00 mg dm^{-3}). In the case of water taken from the wells in Świniarsko (stage iii) and Stary Sącz (stage ix), the average concentrations amounted to 1.96E-01 and 2.79E-01 mg dm^{-3}, respectively. This reflects the hydrogeological conditions at the water intakes. The wells in Świniarsko and Stary Sącz are infiltrated by water from the Dunajec River (strong hydraulic and infiltrative contact with surface water; the wells are relatively shallow, with an average depth of 8–10 m). Hydrogeological conditions near the Mała Wieś water intake direct the flow of ground water towards the river basin. The aquifer used by these wells is not naturally protected against infiltration by a natural isolating layer (consisting of clay or silt). These are low-permeable or impermeable formations that have a positive impact on the natural resistance of water-bearing formations against infiltration of pollutants from the overlying strata or from facilities located nearby that may affect water quality, for example, landfills [30]. The WTPss wells are also artificially fed with water through infiltration basin systems [31]. The higher concentration of microelements and ultratrace elements in the well water at WTPss (Table 1, stage ix) reflects the estimated average concentration values in the river water (stage viii).

3.1.3. Water treated in sand filters (stages v and x)

Considerable differences in element concentrations were found when comparing water samples taken downstream

Table 1a
Basic descriptive statistics of the obtained research results for the microelements in water

Element	Statistic ($\mu g\ dm^{-3}$)	WTPs						WTPss			
		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
	Av.	2.43E+01	2.92E+01	2.01E+01	1.30E+01	1.78E+02	1.06E+02	1.32E+01	1.26E+01	5.34E+01	2.34E+01
B	Max.	5.45E+01	6.67E+01	4.71E+01	3.20E+01	4.50E+02	8.66E+02	3.86E+01	3.34E+01	4.70E+02	4.00E+01
	SD	7.01E-01	6.21E-01	6.39E-01	5.34E-01	6.47E+00	3.75E+00	4.33E-01	2.38E-01	2.04E+00	1.32E+00
	Av.	9.46E+01	1.20E+02	7.89E+01	6.18E+01	2.83E+02	2.70E+02	7.25E+01	6.30E+01	1.56E+02	4.53E+01
Ba	Max.	1.99E+02	2.83E+02	1.72E+02	1.28E+02	7.08E+02	1.46E+03	2.27E+02	1.17E+02	9.03E+02	7.18E+01
	SD	1.48E+00	1.89E+00	1.19E+00	9.13E-01	3.89E+00	3.74E+00	8.88E-01	1.06E+00	1.93E+00	1.49E+00
	Av.	1.85E+00	1.42E+00	1.96E+00	1.75E+00	5.30E+00	3.77E+00	1.45E+00	1.77E+00	4.35E+00	1.98E+00
Cu	Max.	6.70E+00	2.31E+00	5.30E+00	5.38E+00	1.40E+01	2.03E+01	3.88E+00	3.74E+00	2.44E+01	2.17E+00
	SD	2.03E-02	1.42E-02	2.03E-02	3.39E-02	5.94E-02	7.29E-02	6.57E-03	1.06E-02	1.03E-01	4.72E-02
	Av.	2.57E+00	2.99E+00	2.96E+00	2.91E+00	1.97E+01	6.83E+00	2.80E+00	3.02E+00	6.63E+00	4.35E+00
Li	Max.	4.86E+00	5.19E+00	4.96E+00	4.81E+00	5.04E+01	5.22E+01	4.74E+00	5.32E+00	5.01E+01	4.91E+00
	SD	4.17E-02	4.73E-02	4.55E-02	3.20E-02	3.46E-01	5.23E-02	3.91E-02	2.85E-02	5.40E-02	8.30E-02
	Av.	2.49E+00	3.40E+00	4.53E+00	2.66E+01	7.71E+00	9.55E-01	1.73E-01	4.59E+01	7.44E-01	4.84E-01
Mn	Max.	9.55E+00	1.25E+01	3.16E+01	7.71E+01	7.71E+00	1.92E+00	5.59E-01	1.53E+02	6.31E+00	4.84E-01
	SD	3.63E-02	1.92E-02	1.80E-02	2.01E-01	2.76E-02	6.68E-03	1.05E-03	7.70E-01	2.68E-03	1.12E-02
	Av.	3.64E+01	3.22E+01	5.75E+01	5.29E+01	nd	4.57E+01	4.26E+01	8.40E+01	4.08E+01	nd
P	Max.	6.53E+01	5.80E+01	7.33E+01	9.72E+01	nd	8.87E+01	8.32E+01	1.45E+02	7.24E+01	nd
	SD	4.25E+00	4.25E+00	4.25E+00	6.00E+00	nd	7.00E+00	6.75E+00	3.50E+00	5.00E+00	nd
	Av.	1.06E-01	8.44E-02	1.02E-01	2.93E-01	6.95E-01	1.58E-01	1.01E-01	2.82E-01	1.88E-01	1.46E-01
As	Max.	1.74E-04	1.67E-01	2.13E-01	7.67E-01	1.80E+00	1.07E+00	2.78E-01	7.18E-01	1.67E+00	2.82E-01
	SD	7.45E-03	9.40E-03	1.24E-02	1.24E-02	7.43E-02	2.45E-02	1.49E-02	1.11E-02	3.57E-02	4.91E-02
	Av.	1.19E-01	1.25E-01	1.21E-01	1.68E-01	2.96E-01	2.10E-01	8.89E-02	2.01E-01	1.56E-01	8.42E-02
Co	Max.	2.61E-01	2.85E-01	2.80E-01	5.99E-01	6.91E-01	8.87E-01	1.98E-01	4.52E-01	8.96E-01	8.72E-02
	SD	1.82E-03	1.23E-03	1.74E-03	3.10E-03	6.50E-03	9.53E-03	1.92E-03	2.63E-03	7.19E-03	2.41E-03
	Av.	8.86E-01	6.57E-01	8.58E-01	9.95E-01	7.54E-01	3.74E+00	1.01E+00	1.89E+00	9.39E-01	7.95E-01
Cr	Max.	3.54E+00	2.25E+00	3.46E+00	3.37E+00	1.52E+00	3.10E+01	3.58E+00	1.31E+01	5.05E+00	1.66E+00
	SD	1.08E-02	1.65E-02	9.29E-03	2.92E-02	1.50E-01	9.60E-02	3.04E-02	1.18E-01	1.33E-01	9.05E-02
	Av.	1.71E+00	4.75E-01	1.30E+00	6.75E-01	nd	2.69E-01	0.00E+00	0.00E+00	1.32E-02	nd
I	Max.	8.53E+00	2.38E+00	6.52E+00	3.38E+00	nd	1.34E+00	0.00E+00	0.00E+00	6.60E-02	nd
	SD	2.00E-01	2.00E-01	0.00E+00	0.00E+00	nd	2.00E-01	0.00E+00	2.00E-01	2.00E-01	nd
	Av.	6.74E-01	3.90E-01	3.59E-01	8.01E-01	1.72E+00	8.93E-01	3.02E-01	3.66E-01	6.80E-01	4.34E-01
Mo	Max.	3.54E+00	2.51E+00	1.95E+00	5.99E+00	4.53E+00	7.46E+00	1.12E+00	1.82E+00	2.99E+00	4.50E-01
	SD	8.49E-03	4.58E-03	7.91E-03	9.12E-02	1.07E-01	1.77E-01	7.54E-03	6.50E-03	1.17E-01	3.10E-02
	Av.	9.71E-01	7.73E-01	8.59E-01	9.94E-01	1.91E+00	1.14E+00	6.59E-01	1.04E+00	6.54E-01	3.46E-01
Ni	Max.	2.48E+00	1.50E+00	2.88E+00	2.16E+00	4.80E+00	3.53E+00	2.39E+00	1.82E+00	2.63E+00	3.73E-01
	SD	1.34E-02	8.64E-03	1.16E-02	1.42E-02	1.48E-01	5.75E-02	1.23E-02	1.63E-02	4.80E-02	1.45E-02

Table 1a Continued

Element	Statistic ($\mu g\ dm^{-3}$)	WTPs						WTPss			
		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
	Av.	5.59E-01	4.38E-01	6.35E-01	1.11E+00	nd	2.83E-01	7.19E-01	1.34E+00	5.41E-01	nd
Rb	Max.	7.96E-01	5.21E-01	1.48E+00	1.91E+00	nd	4.86E-01	1.11E+00	1.81E+00	1.33E+00	nd
	SD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd
	Av.	4.65E-02	3.85E-02	4.42E-02	6.98E-02	4.59E-01	8.99E-02	5.91E-02	6.67E-02	1.39E-01	1.33E-01
Sb	Max.	1.17E-01	1.10E-01	1.23E-01	1.83E-01	1.16E+00	7.80E-01	1.66E-01	1.73E-01	1.16E+00	1.42E-01
	SD	4.29E-03	3.17E-03	2.51E-03	3.22E-03	4.84E-02	7.49E-03	2.53E-03	2.86E-03	1.60E-02	4.82E-03
	Av.	2.55E-01	2.75E-01	1.35E-01	4.44E-02	7.98E-01	7.92E-01	7.96E-02	5.99E-02	4.43E-01	1.08E-01
Se	Max.	7.76E-01	1.04E+00	3.61E-01	1.49E-01	1.53E+00	5.08E+00	3.56E-01	2.98E-01	4.07E+00	2.09E-01
	SD	1.39E-01	7.23E-02	1.21E-01	2.39E-02	3.73E-01	1.90E-01	4.42E-02	4.53E-02	3.11E-01	9.10E-02
	Av.	0.00E+00	1.27E-02	0.00E+00	4.99E-01	nd	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd
Sn	Max.	0.00E+00	8.90E-02	0.00E+00	3.49E+00	nd	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd
	SD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd
	Av.	1.77E-01	1.46E-01	1.70E-01	3.46E-01	5.65E-01	2.30E-01	1.45E-01	3.53E-01	1.89E-01	1.29E-01
V	Max.	4.59E-01	3.57E-01	3.45E-01	1.33E+00	1.41E+00	7.33E-01	2.69E-01	7.44E-01	8.82E-01	1.66E-01
	SD	3.97E-03	3.37E-03	2.82E-03	1.22E-02	2.63E-02	1.52E-02	3.57E-03	5.65E-03	1.12E-02	1.17E-02
Total Av.		**1.68E+02**	**1.92E+02**	**1.71E+02**	**1.65E+02**	**5.01E+02**	**4.41E+02**	**1.36E+02**	**2.16E+02**	**2.66E+02**	**7.77E+01**

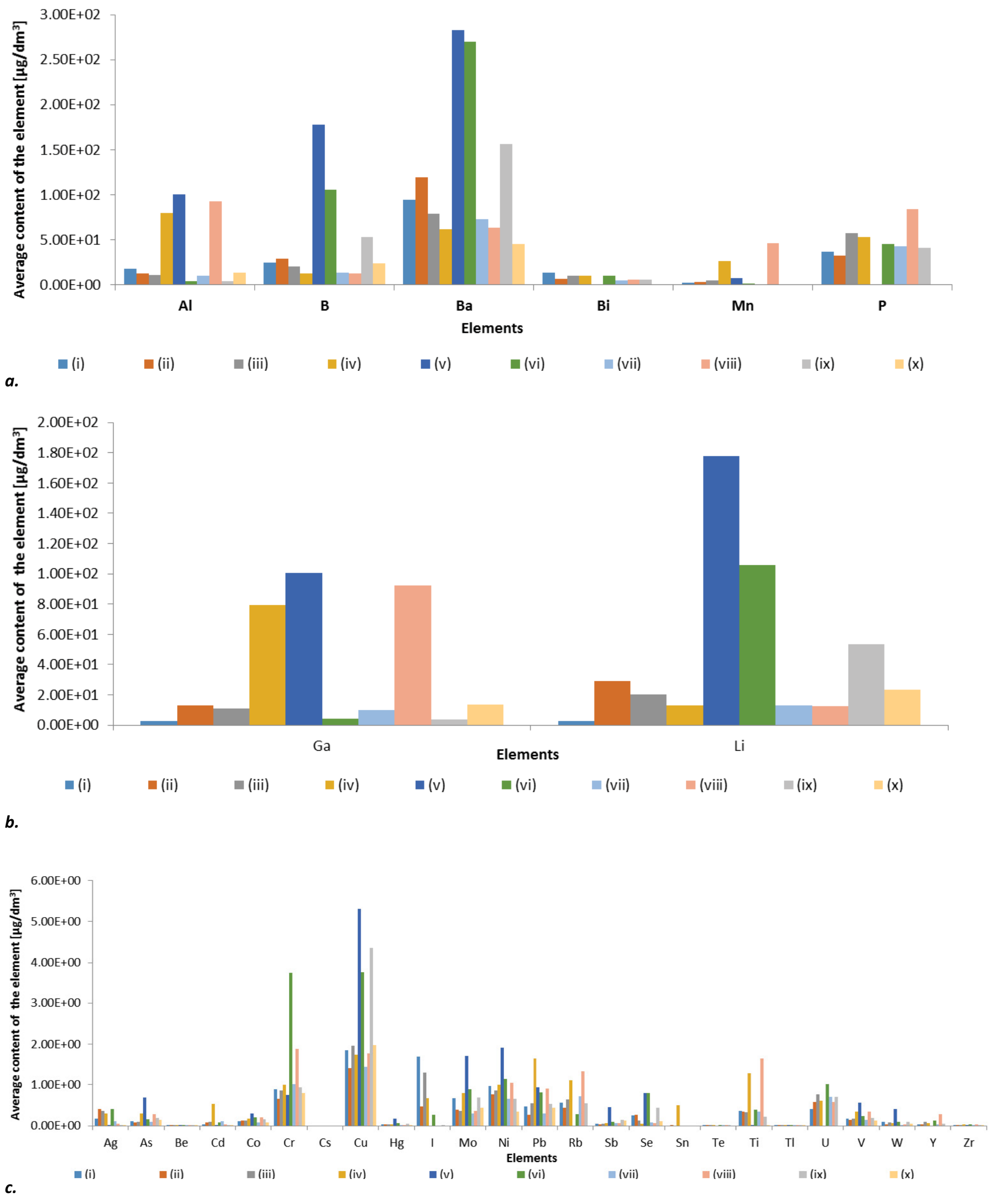
Table 1b
Basic descriptive statistics of the obtained research results for the ultraelements in water

Element	Statistic ($\mu g\ dm^{-3}$)	WTPs						WTPss			
		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
	Av.	1.80E-01	4.03E-01	3.58E-01	3.01E-01	2.36E-02	4.07E-01	1.13E-01	5.14E-02	1.87E-02	3.00E-03
Ag	Max.	1.18E+00	4.66E+00	4.20E+00	2.31E+00	5.81E-02	4.50E+00	7.93E-01	5.55E-01	1.25E-01	5.61E-03
	SD	5.65E-04	7.06E-04	8.38E-02	5.57E-04	8.56E-03	1.65E-03	4.80E-04	4.58E-04	1.33E-03	7.00E-04
	Av.	1.38E+01	6.69E+00	9.98E+00	9.81E+00	nd	9.60E+00	4.93E+00	5.50E+00	5.54E+00	nd
Bi	Max.	3.63E+01	1.13E+01	2.68E+01	2.21E+01	nd	2.39E+01	9.42E+00	1.42E+01	1.37E+01	nd
	SD	1.00E+00	0.00E+00	1.00E+00	2.50E-01	nd	7.50E-01	2.50E-01	2.50E-01	2.50E-01	nd
	Av.	1.03E-01	3.13E-02	8.14E-02	7.04E-02	4.14E-01	9.35E-02	1.38E-02	2.73E-02	9.65E-02	4.59E-02
W	Max.	7.95E-01	1.82E-01	6.32E-01	6.22E-01	9.29E-01	9.40E-01	8.24E-02	1.50E-01	9.58E-01	8.18E-02
	SD	7.02E-03	3.12E-03	8.27E-03	8.04E-03	5.30E-02	5.62E-03	2.60E-03	3.90E-03	1.87E-02	6.10E-03
Total Av.		**1.41E+01**	**7.13E+00**	**1.04E+01**	**1.02E+01**	**4.37E-01**	**1.01E+01**	**5.06E+00**	**5.58E+00**	**5.65E+00**	**4.89E-02**

Table 1c
Basic descriptive statistics of the obtained research results for the another elements in water

Element	Statistic ($\mu g\ dm^{-3}$)	WTPs						WTPss			
		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
	Av.	1.81E+01	1.28E+01	1.11E+01	7.94E+01	1.00E+02	3.97E+00	9.71E+00	9.24E+01	3.55E+00	1.35E+01
Al	Max.	3.39E+01	1.95E+01	6.20E+01	5.07E+02	2.49E+02	1.62E+01	1.99E+01	2.99E+02	1.74E+01	2.28E+01
	SD	3.60E-01	2.33E-01	3.25E-01	4.25E+00	1.02E+01	5.32E-02	2.29E-01	2.46E+00	1.27E-01	5.08E-01
	Av.	4.66E-01	2.64E-01	5.46E-01	1.66E+00	9.43E-01	8.08E-01	3.06E-01	9.04E-01	5.35E-01	4.42E-01
Pb	Max.	2.52E+00	6.17E-01	2.42E+00	1.46E+01	2.14E+00	5.10E+00	1.47E+00	5.79E+00	4.68E+00	5.03E-01
	SD	8.87E-02	2.06E-03	5.47E-03	7.05E-03	2.21E-02	1.23E-02	6.65E-03	9.06E-02	8.90E-03	1.92E-02
	Av.	1.20E-03	1.62E-04	1.76E-03	4.92E-03	2.53E-04	7.62E-04	5.40E-04	6.50E-03	2.35E-04	1.80E-04
Be	Max.	4.82E-03	1.31E-03	1.50E-02	3.90E-02	7.58E-04	5.00E-03	3.00E-03	3.01E-02	1.75E-03	5.38E-04
	SD	2.10E-04	7.18E-04	6.80E-04	9.94E-04	1.10E-02	3.15E-03	8.78E-04	9.07E-04	4.55E-03	3.00E-03
	Av.	3.42E-02	7.94E-02	9.12E-02	5.30E-01	2.11E-02	8.19E-02	1.11E-01	4.20E-02	2.29E-02	5.24E-03
Cd	Max.	1.57E-01	6.10E-01	6.52E-01	6.09E+00	5.05E-02	7.32E-01	1.15E+00	1.33E-01	1.18E-01	5.84E-03
	SD	1.08E-03	9.98E-04	9.64E-04	1.33E-03	9.08E-03	3.70E-03	5.91E-04	2.35E-03	9.60E-03	1.39E-03
	Av.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd
Cs	Max.	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd
	SD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd
	Av.	2.51E+00	3.17E+00	2.21E+00	1.90E+00	nd	3.98E+00	2.49E+00	2.08E+00	2.13E+00	nd
Ga	Max.	3.37E+00	4.39E+00	2.99E+00	2.44E+00	nd	5.15E+00	3.60E+00	2.32E+00	2.83E+00	nd
	SD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd
	Av.	3.40E-02	3.01E-02	3.83E-02	3.65E-02	1.70E-01	5.95E-02	2.67E-02	2.10E-02	4.30E-02	2.27E-02
Hg	Max.	1.02E-01	1.15E-01	1.69E-01	1.37E-01	4.39E-01	4.67E-01	7.69E-02	8.49E-02	2.96E-01	2.73E-02
	SD	2.94E-03	2.60E-03	2.43E-03	2.70E-03	3.55E-02	5.38E-03	1.93E-03	1.52E-03	8.56E-03	2.55E-03
	Av.	8.29E-03	1.37E-02	1.23E-02	6.43E-03	nd	9.29E-03	1.26E-02	1.23E-02	5.29E-03	nd
Te	Max.	4.40E-02	4.00E-02	3.70E-02	1.80E-02	nd	2.70E-02	4.60E-02	3.90E-02	1.80E-02	nd
	SD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd
	Av.	3.61E-01	3.48E-01	3.30E-01	1.29E+00	1.48E-02	3.94E-01	3.39E-01	1.65E+00	2.15E-01	2.10E-02
Ti	Max.	1.90E+00	1.42E+00	2.04E+00	5.51E+00	2.68E-02	2.25E+00	2.24E+00	4.97E+00	1.52E+00	4.54E-02
	SD	9.20E-02	2.38E-02	2.91E-01	4.21E-01	2.08E-02	1.35E-01	9.49E-02	2.37E-01	1.42E-01	2.14E-02
	Av.	9.08E-04	6.08E-04	4.26E-04	2.73E-03	7.14E-03	7.70E-04	8.89E-04	2.05E-03	8.33E-04	2.02E-03
Tl	Max.	3.78E-03	1.90E-03	1.41E-03	1.02E-02	1.89E-02	7.37E-03	2.76E-03	6.71E-03	7.37E-03	2.56E-03
	SD	1.64E-04	1.29E-04	1.36E-04	2.20E-04	1.67E-03	4.60E-04	9.73E-05	2.14E-04	3.70E-04	3.59E-04
	Av.	4.06E-01	5.75E-01	7.73E-01	6.13E-01	nd	1.02E+00	6.99E-01	5.77E-01	7.04E-01	nd
U	Max.	5.66E-01	9.97E-01	1.19E+00	8.37E-01	nd	1.58E+00	1.17E+00	7.69E-01	1.02E+00	nd
	SD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd
	Av.	1.66E-02	1.52E-02	2.21E-02	3.70E-02	1.79E-02	2.75E-02	1.95E-02	4.25E-02	2.34E-02	7.59E-03
Zr	Max.	6.20E-02	6.90E-02	8.50E-02	8.10E-02	3.80E-02	1.82E-01	1.16E-01	7.80E-02	1.73E-01	9.88E-03
	SD	1.08E-03	1.66E-03	1.03E-03	8.19E-03	1.43E-02	7.09E-03	1.57E-02	3.06E-03	4.49E-03	2.93E-03
	Av.	3.60E-02	4.08E-02	9.58E-02	7.33E-02	nd	1.28E-01	2.90E-02	2.80E-01	4.33E-02	nd
Y	Max.	7.60E-02	5.80E-02	1.83E-01	1.12E-01	nd	2.27E-01	6.90E-02	7.11E-01	6.20E-02	nd
	SD	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd	0.00E+00	0.00E+00	0.00E+00	0.00E+00	nd
Total Av.		**2.20E+01**	**1.73E+01**	**1.52E+01**	**8.55E+01**	**1.02E+02**	**1.05E+01**	**1.37E+01**	**9.80E+01**	**7.28E+00**	**1.40E+01**

Explanations:
(i) treated water directed to the water supply network from WTPs (water intake on the first day); (ii) treated water directed to the water supply network from WTPs (water intake the next day); (iii) 16 infiltration wells in Świniarsko supplying WTPs; (iv) surface intake on the Dunajec River in Świniarsko supplying WTPs; (v) water after sand filters during the technological process in WTPs; (vi) 11 infiltration wells in Mała Wieś supplying WTPs; (vii) treated water directed to the water supply network from WTPss; (viii) surface intake on the Dunajec River in Stary Sącz supplying the WTPss; (ix) infiltration wells in Stary Sącz supplying WTPss; (x) water after sand filters during the technological process at WTPss.
Av. – average concentration value; SD – standard deviation (–); Max. – maximum concentration value; nd – non-research.



Explanations:
(i)...(x) Look at the Table 1

Fig. 2. Contents of microelements: with a share in the total concentration of >5% (a), with a share in the total concentration of 1%–5% (b), with a share in the total concentration of <1% (c).

of sand filters during the treatment process conducted at WTPs (stage v) and WTPss (stage x). After passing through the sand filters at WTPs (stage v), the water had 85% higher concentration of dissolved elements as compared to the water at WTPss (stage x). The average concentration was 6.03E-01 mg dm^{-3} in the case of (v) and 9.18E-02 mg dm^{-3} in the case of (x). The elements having the greatest impact on the concentration levels at both sampling sites were Ba (47%–49%), B (25%–29%) and Al (15%–17%). Al is particularly important from the perspective of human health. Its considerable amount in the water that passed through the sand filters stems from its concentration in the river and well water. Some proportion of Al may also be related to the use of aluminium coagulants in the water treatment process. However, it should be noted that none of the treated water samples contained an amount of Al that would exceed the values set in the standards applicable to drinking water. The share of Al in the treated water amounted to 6%–9% of all dissolved elements. At the same time, the dispersion of the results was the highest for the sand filter stage at both plants, with the CV ranging from 91% to 211%.

3.1.4. Treated water supplied to the water distribution system (stages i, ii and vii)

Water supplied to the water distribution system from WTPs (stages i and ii) and WTPss (stage vii) proved to be most relevant for the analysis of the impact of water on

Table 2
Series of average concentrations of parameters depending on the place of water sampling

Place where the water sample is taken	Series of average concentrations of parameters
(i)	Ba > P > B > Al > Bi > Li > Ga > Mn > Cu > I > Ni > Cr > Mo > Rb > Pb > U > Ti > Se > Ag > V > Co > As > W > Sb > Y > Cd > Hg > Zr > Te > Be > Tl > Cs > Sn
(ii)	Ba > P > B > Al > Bi > Mn > Ga > Li > Cu > Ni > Cr > U > I > Rb > Ag > Mo > Ti > Se > Pb > V > Co > As > Cd > Y > Sb > W > Hg > Zr > Te > Sn > Tl > Be > Cs
(iii)	Ba > P > B > Al > Bi > Mn > Li > Ga > Cu > I > Ni > Cr > U > Rb > Pb > Mo > Ag > Ti > V > Se > Co > As > Y > Cd > W > Sb > Hg > Zr > Te > Be > Tl > Cs > Sn
(iv)	Al > Ba > P > Mn > B > Bi > Li > Ga > Cu > Pb > Ti > Rb > Cr > Ni > Mo > I > U > Cd > Sn > V > Ag > As > Co > Y > W > Sb > Se > Zr > Hg > Te > Be > Tl > Cs
(v)	Ba > B > Al > Li > Mn > Cu > Ni > Mo > Pb > Se > Cr > As > V > Sb > W > Co > Hg > Ag > Cd > Zr > Ti > Tl > Be…[a]
(vi)	Ba > B > P > Bi > Li > Ga > Al > Cu > Cr > Ni > U > Mn > Mo > Pb > Se > Ag > Ti > Rb > I > V > Co > As > Y > W > Sb > Cd > Hg > Zr > Te > Tl > Be > Cs > Sn
(vii)	Ba > P > B > Al > Bi > Li > Ga > Cu > Cr > Rb > U > Ni > Ti > Pb > Mo > Mn > V > Ag > Cd > As > Co > Se > Sb > Y > Hg > Zr > W > Te > Tl > Be > Cs > I > Sn
(viii)	Al > P > Ba > Mn > B > Bi > Li > Ga > Cr > Cu > Ti > Rb > Ni > Pb > U > Mo > V > As > Y > Co > Sb > Se > Ag > Zr > Cd > W > Hg > Te > Be > Tl > Cs > I > Sn
(ix)	Ba > B > P > Li > Bi > Cu > Al > Ga > Cr > Mn > U > Mo > Ni > Rb > Pb > Se > Ti > V > As > Co > Sb > W > Y > Hg > Zr > Cd > Ag > I > Te > Tl > Be > Cs > Sn
(x)	Ba > B > Al > Li > Cu > Cr > Mn > Pb > Mo > Ni > As > Sb > V > Se > Co > W > Hg > Ti > Zr > Cd > Ag > Tl > Be…[b]

[a]not marked: Bi. Cs. Ga. I. P. Rb. Sn. Te. U. Y.
[b]not marked: Bi. Cs. Ga. Hg. I. Li. Mn. Ni. P. Se. Te. U. V. Y. Zr.
Explanations: Look at the Table 1.

human health. In the case of WTPs, the comparison of the two samples of treated water, collected twice in a given month within 1 d of each other to reflect the changes in the water pumping method, revealed negligible changes in the dispersion of the average element concentrations. On the first sampling day, the values formed the following sequence: Ba > P > B > Al > Bi > Li > Ga > Mn > Cu and were almost identical to those observed on the second sampling day (Table 1, Fig. 2). The very similar sequences of the average values of the parameters tested reflect the concentrations found in surface water from the Dunajec River (Table 2). Determining the variance of individual variables allowed for evaluating the stability of the chemical composition of water supplied to the public water distribution system. In the case of WTPs, it amounted to 6.55E-01 (stages i and ii), with the CV of 7%–19%, and in the case of WTPss (stage vii) it was 4.82E-01, with the CV of 14%.

3.2. Doses of bioelements ingested through water

3.2.1. Water from intakes supplying the water distribution system

Another important research objective was to calculate the chronic daily intake (CDI) of substances ingested through water by children and adults (Table 3). The analysis focused on microelements and ultratrace elements essential for the proper functioning of the human body. The estimated average daily doses of selected elements (Al, As, Cd, Co, Cr, Cu, Mn, Mo, Ni, P, Sn) ingested through tap water were compared with the recommended daily intake (RDI) values published by Kicińska et al. [29].

The results of the analysis are presented in Fig. 3A–J. The quantities of microelements ingested through tap water provided up to 0.15% of the RDI. Cr found in water from the infiltration wells in Mała Wieś (stage vi) was the most prevalent among all the elements analysed. This reflects the fact that among all the intakes the highest average concentration of this element (3.74E-03 mg dm^{-3}) was found in water taken from the wells. As a result of mixing river water (stage iv) with well water (stages iii and vi) at WTPs, the average quantity of Cr in treated water directed to the water distribution system (stages i and ii) is reduced to 0.02%–0.03% of the RDI.

The consumption of water from the water distribution system meets the RDI for the elements analysed to a similar degree in the case of adults and children. In children, the RDI for Mn, Mo and Sn (non-carcinogenic parameters) was met to slightly higher degree than in adults. The RDI for all the potential carcinogenic elements (Al, As, Cd, Cr, Ni) was covered to a higher extent in adults as compared to children. This is due to the unified value of the AT coefficient for children and adults (25,550) for potentially carcinogenic parameters and the lower body weight of children and their lower water consumption. Among the non-carcinogenic parameters, the RDI for Cu and P was met to a slightly higher degree in children. The RDI for these elements is lower for children than for adults [29] by 0.5 mg d^{-1} (Cu) and by 200 mg d^{-1} (P).

When comparing the types of sampling sites (raw water from the river, treated well water), it was demonstrated

Table 3
Calculation of daily average doses of uptake substances (CDI) and recommended daily intake (RDI) for individual components

Element		(mg kg^{-1} bw d^{-1})										
		RDI[c]	CDI average calculated									
			WTPs						WTPss			
			(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)
Al	*a*	5.7	6.00E-07	1.35E-06	1.20E-06	1.01E-06	7.88E-08	1.36E-06	3.79E-07	1.72E-07	6.26E-08	1.00E-08
	b	20	3.38E-06	5.35E-06	4.75E-06	4.00E-06	3.12E-07	5.41E-06	1.50E-06	6.82E-07	2.48E-07	3.99E-08
As	*a*	0.04	3.56E-07	2.82E-07	3.40E-07	9.80E-07	2.32E-06	5.28E-07	3.37E-07	9.44E-07	6.27E-07	4.90E-07
	b	0.15	1.41E-06	1.12E-06	1.35E-06	3.89E-06	9.23E-06	2.09E-06	1.34E-06	3.75E-06	2.49E-06	1.94E-06
B	*a*		9.49E-04	1.14E-03	7.85E-04	5.06E-04	6.94E-03	4.13E-03	5.16E-04	4.92E-04	2.08E-03	9.12E-04
	b		2.53E-03	3.04E-03	2.10E-03	1.35E-03	1.85E-02	1.10E-02	1.38E-03	1.31E-03	5.56E-03	2.44E-03
Ba	*a*		3.69E-03	4.66E-03	3.08E-03	2.41E-03	1.10E-02	1.05E-02	2.83E-03	2.46E-03	6.08E-03	1.77E-03
	b		9.85E-03	1.24E-02	8.22E-03	6.43E-03	2.95E-02	2.81E-02	7.56E-03	6.56E-03	1.62E-02	4.72E-03
Bi	*a*		5.40E-04	2.61E-04	3.89E-04	3.82E-04		3.74E-04	1.92E-04	2.15E-04	2.16E-04	
	b		1.44E-03	6.97E-04	1.04E-03	1.02E-03		1.00E-03	5.13E-04	5.73E-04	5.77E-04	
Cd	*a*	0.02	1.14E-07	2.66E-07	3.05E-07	1.77E-06	7.05E-08	2.74E-07	3.72E-07	1.40E-07	7.64E-08	1.75E-08
	b	0.07	4.53E-07	1.05E-06	1.21E-06	7.03E-06	2.80E-07	1.09E-06	1.48E-06	5.57E-07	3.03E-07	6.94E-08
Cr	*a*	0.01	2.95E-06	2.20E-06	2.87E-06	3.33E-06	2.52E-06	1.25E-05	3.39E-06	6.32E-06	3.14E-06	2.66E-06
	b	0.035	1.18E-05	8.71E-06	1.14E-05	1.32E-05	1.00E-05	4.96E-05	1.35E-05	2.51E-05	1.25E-05	1.05E-05
Cu	*a*	0.4	7.23E-05	5.54E-05	7.64E-05	6.82E-05	2.07E-04	1.47E-04	5.67E-05	6.92E-05	1.70E-04	7.73E-05
	b	0.9	1.93E-04	1.48E-04	2.04E-04	1.82E-04	5.52E-04	3.93E-04	1.51E-04	1.85E-04	4.53E-04	2.06E-04
Ga	*a*		9.80E-05	1.24E-04	8.62E-05	7.43E-05		1.55E-04	9.70E-05	8.10E-05	8.31E-05	
	b		2.62E-04	3.30E-04	2.30E-04	1.98E-04		4.15E-04	2.59E-04	2.16E-04	2.22E-04	
Li	*a*		1.00E-04	1.17E-04	1.15E-04	1.13E-04	7.68E-04	2.66E-04	1.09E-04	1.18E-04	2.59E-04	1.70E-04
	b		2.68E-04	3.12E-04	3.08E-04	3.03E-04	2.05E-03	7.11E-04	2.92E-04	3.14E-04	6.91E-04	4.53E-04
Mn	*a*	60	9.71E-05	1.33E-04	1.76E-04	1.04E-03	3.01E-04	3.72E-05	6.76E-06	1.79E-03	2.90E-05	
	b	210	2.59E-04	3.54E-04	4.71E-04	2.77E-03	8.03E-04	9.95E-05	1.81E-05	4.78E-03	7.75E-05	
Mo	*a*	5	2.63E-05	1.52E-05	1.40E-05	3.12E-05	6.71E-05	3.48E-05	1.18E-05	1.43E-05	2.65E-05	1.69E-05
	b	17.5	7.02E-05	4.07E-05	3.74E-05	8.34E-05	1.79E-04	9.31E-05	3.14E-05	3.81E-05	7.09E-05	4.52E-05
Ni	*a*	0.1	3.25E-06	2.58E-06	2.87E-06	3.32E-06	6.40E-06	3.80E-06	2.20E-06	3.49E-06	2.19E-06	1.16E-06
	b	0.35	1.29E-05	1.03E-05	1.14E-05	1.32E-05	2.54E-05	1.51E-05	8.75E-06	1.39E-05	8.68E-06	4.59E-06
P	*a*	500	1.42E-03	1.26E-03	2.24E-03	2.06E-03		1.78E-03	1.66E-03	3.28E-03	1.59E-03	
	b	700	3.79E-03	3.35E-03	5.99E-03	5.51E-03		4.76E-03	4.44E-03	8.75E-03	4.25E-03	
Sn	*a*	40	0.00E+00	4.96E-07	0.00E+00	1.95E-05		0.00E+00	0.00E+00	0.00E+00	0.00E+00	
	b	140	0.00E+00	1.32E-06	0.00E+00	5.20E-05		0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Total	*a*	611.27	1.62E-03	1.47E-03	2.52E-03	3.23E-03	5.86E-04	2.02E-03	1.74E-03	5.16E-03	1.82E-03	9.85E-05
	b	1 089.01	1.63E-03	1.47E-03	2.52E-03	3.24E-03	6.15E-04	2.06E-03	1.75E-03	5.15E-03	1.83E-03	1.11E-04

Explanations:
(i) … (x) Look at the Table 1;
[a]for children (bw = 20 kg);
[b]for adults (bw = 70 kg);
[c]RDI – recommended daily intake [29];
bold – dominated components.

that, in line with the additivity principle, water from the Dunajec water intake in Stary Sącz (stage viii) met the average total RDI for the microelements and ultratrace elements analysed to the highest extent, with 0.005 mg d^{-1} for children and adults. The values determined for surface water intake in Świniarsko (iv) were also similar – 0.003 mg d^{-1} in children and for adults. The highest RDI coverage was found in the intakes in Świniarsko (iii and vi). The CDI for these intakes was 0.002 mg d^{-1} for children and adults, respectively. The well intake in Stary Sącz (ix) provides 0.001 mg d^{-1} coverage for children and adults for the microelements tested (Table 3).

Water treated at WTPs, collected on the second day (stage ii), met the RDI for Al to a higher extent as compared to the samples taken on the first day (however, the amount was still very small: 0.00002%). This reflects the

Fig. 3. Charts of coverage of the recommended daily amounts of supply to the body of selected bioelements as a result of water consumption by children and adults for: Al, As, Cd, Cr, Cu, Mn, Mo, Ni, P, Sn.

concentration of this element in the well water (vi) and the increased share of the water pumped from these wells in the water distribution system. Considering the microelements analysed in total, the treated water directed to the water distribution system provides on average from 0.0002 (WTPs) to 0.0003% (WTPss) of the RDI for children and from 0.0001% (WTPs) to 0.0002% (WTPss) of the RDI for adults.

The CDI for treated water taken on the second sampling day (ii) was comparable to the first day (i), despite the higher bioelement concentration in the well water (vi). The daily intake of selected bioelements following the consumption of water from the public distribution system was in line with the values predicted. Water is the main medium for transporting nutrients, rather than their main source for the human body.

3.2.2. Bottled water

The calculated daily intake of selected bioelements from water was compared with the doses provided through daily consumption of bottled water. Information on the

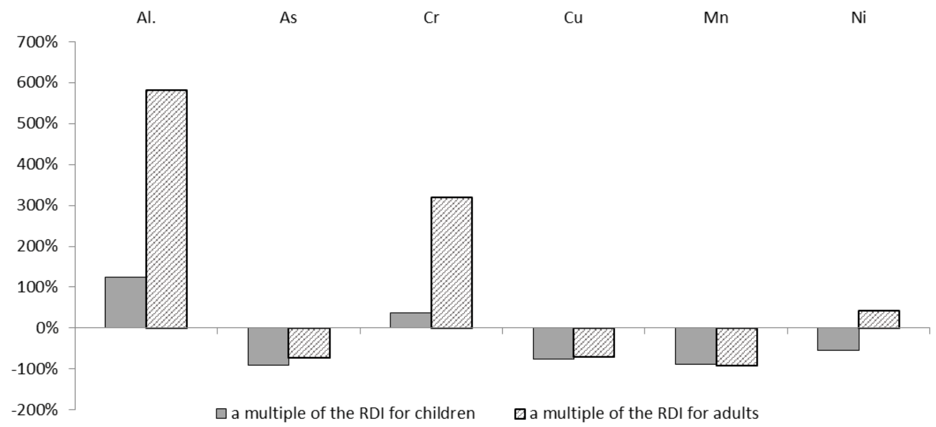


Fig. 4. Doses delivered (CDI) as a result of continuous consumption of bottled water in relation to the recommended doses (RDI) for children and adults.

mineralisation levels was collected from the available resources for four groups of bottled water (high-, medium- and low-mineral water, and medicinal water – as a separate category). The data are presented in Table 4.

The following water types were distinguished: 7 types of high-mineral water (containing from 1991.6 to 2896.3 mg dm^{-3} of minerals), 10 types of medium-mineral water (containing from 500.3 to 1409.0 mg dm^{-3} of minerals) and 6 types of low-mineral water (containing from 93 to 489 mg dm^{-3} of minerals). The table also presents the content of cations (Na^+, Ca^{2+}, Mg^{2+}, K^+, Li^+, Fe^{2+}) and anions (Cl^-, SO_4^{2-}, HCO_3^-, F^-, I^-) in different types of mineral water, which varied from several to several dozen mg dm^{-3}. Moreover, 6 types of medicinal water were analysed, with high mineralisation and/or content of specific elements such as Fe^{2+}, I^-, F^-, SO_4^{2-}, Cl, Li^+, and Na^+.

The concentrations of selected microelements in the mineral water analysed are presented in Table 5. As the calculations were based on microdata regarding the content of individual elements, the mean value estimation was not used. The bottled water displayed a considerable dispersion of individual bioelement concentrations, depending on the water type.

Table 6 presents CDI calculations for Al, As, Co, Cr, Cu, Mn, Ni, and P for children and adults consuming bottled water only.

A comparative analysis of individual microelement concentrations in water treated at WTPs and WTPss vs. selected types of mineral water demonstrated that mineral water satisfies the demand for microelements to a considerably higher extent than water from WTP (Table 3). The CDI values for specific elements found in mineral water also exceeded the RDI. The RDI [29] was exceeded in the case of Al and Cr for both adults and children, and the RDI for Ni was exceeded for adults in the following way: Al – over 2 times for children and about 7 times for adults (no. of bottled water: 7, 9, 26, 29); Cr – 1 time for children (no. of bottled water: 5, 14, 19, 23–25); and 4 times for adults (no. of bottled water: 5, 12, 14, 18, 19, 23–25); Ni – 1.5 times for adults (no. of bottled water: 10). Al and Ni content was exceeded mainly in healing waters, and Cr in moderately mineralized waters. The RDI was not exceeded for the other parameters compared, but it was met to a considerable degree. Carcinogenic parameters are of particular importance when analysing water for human consumption. It was found that the average concentration of As provided 9% RDI for children and 27% for adults, Cr: 37% RDI and Ni: 46% RDI for adults (Fig. 4).

4. Discussion

According to the WHO guidelines and the available literature, the recommended doses of microelements depend on a number of factors, which are similar to those determining the hydration level in the human body, as indicated above. Table 7 presents the function of selected elements (mostly microelements) and their recommended amounts ingested through food and water. Many among the elements discussed can be both beneficial for human health and toxic, depending on the dose ingested (e.g., Se As, Cd, Ni, Zn). Exceeding the permissible concentration of these elements may result in carcinogenesis, while their deficiency may impair natural physiological processes and biochemical changes in which they [36]. Thus, it is very difficult to estimate reference doses for each of the microelements essential to the proper functioning and maintaining good health.

Over the years, bottled water has become increasingly popular among consumers [37,38]. In the majority of developing countries, the consumption of bottled water increased from 45 to 53 dm^3 person y^{-1} in the years 2015–2020 (Fig. 5). This may stem from its widespread availability and the effectiveness of marketing campaigns [39]. However, it is worth noting that at the same time the consumption of bottled water in Germany decreased from 138 dm^3 person^{-1} in 2015 to 126 dm^3 person^{-1} in 2020. This may be caused by a new trend, that is, the increased consumption of water from distribution systems – “straight from the tap” – whose chemical composition is similar to that of low-mineral water.

The European Parliament pays particular attention to the quality of water provided to consumers through water distribution systems, which may result in further increase in the consumption of tap water in the nearest future. The quality of bottled water may also be affected by the packaging

Table 4
Mineralization levels and the content of dissolved ions in selected bottled waters

Numbers of bottled water	Mineralization (mg dm^{-3})	Cations						Anions				
		Na^+	Ca^{2+}	Mg^{2+}	K^+	Li^+	Fe^{2+}	Cl^-	SO_4^{2-}	HCO_3^-	F^-	I^-
Low-mineralized waters												
22	248.3	1.8	48.10	6.08	0.86	–	–	4.20	13.78	160.11	0.120	–
3	93.0	5.1	44.70	5.10	0.40	0.00		5.20	17.70	125.00	0.100	
4	420.0	2.0	58.12	33.42	–	–	–	–	–	276.94	0.130	–
15	472.2	8.0	71.14	25.52	1.44	–	–	6.70	39.09	307.50	0.150	–
8	430.0	5.0	42.00	21.60	0.90	–	–	4.50	14.50	278.50	0.140	–
5	489.0	6.5	80.00	26.00	1.00	–	–	6.80	12.60	360.00	–	–
Moderately mineralized waters												
11	500.3	10.0	66.10	32.80	2.20	–	–	7.80	40.50	329.90	0.400	–
12	508.7	9.2	86.97	12.82	3.46	–	–	5.32	12.60	360.01	0.060	–
23	630.0	5.4	101.00	26.20	3.40	–	–	13.50	37.00	442.40	–	–
6	513.0	–	–	–	–	–	–	–	–	–	–	–
18	650.0	10.0	114.20	20.00	2.50	–	–	12.60	–	448.10	0.300	–
17	1,255.0	80.6	159.30	50.40	6.00	–	–	6.40	17.50	918.20	0.200	–
19	708.0	11.8	155.00	6.80	–	–	–	25.00	46.10	445.00	–	–
2	742.0	11.0	130.30	21.90	<5	–	–	<5	<1	539.10	<0.5	–
24	998.0	33.3	174.00	51.40	–	–	–	52.00	430.00	245.00	–	–
1	1,409.0	256.0	74.00	15.00	7.00	–	–	338.00	24.00	584.00	0.400	0.5
Highly mineralized waters												
21	1,729.0	133.0	180.00	87.00	13.00	0.60	–	–	32.00	1,260.00	0.220	–
20	2,146.0	53.0	368.90	73.00	5.10	–	–	10.00	6.23	1,650.00	0.130	–
26	1,991.6	420.0	94.00	35.00	–	–	–	212.70	–	1,141.00	–	0.3
16	2,104.0	98.0	240.00	120.00	9.00	–	–	10.00	27.00	1,600.00	–	–
13	2,246.0	56.0	367.90	74.00	5.27	–	–	10.43	6.15	1,722.00	0.140	–
14	2,246.1	54.7	368.92	73.21	5.27	–	–	10.30	6.15	1,721.90	0.140	–
28	2,896.3	619.9	142.50	47.90	–	–	–	319.10	–	1,665.80	–	0.5
Healing waters												
25	3,243.6	267.4	195.20	211.20	10.31	–	0.11	15.10	3.00	2,479.30	0.110	–
9	5,225.6	1,231.0	156.70	39.00	33.00	1.00	–	585.00	11.70	2,989.90	0.500	0.9
7	14,814.3	4,040.0	176.40	19.60	80.80	2.50	–	2,162.90	11.70	7,853.00	–	2.9
29	25,006.3	6,168.0	77.43	363.80	288.40	18.53	0.43	902.00	3.00	17,161.00	0.097	1.1
10	669.9	15.7	115.71	17.61	1.67	0.01	0.22	43.70	49.24	343.10	0.206	–
27	1,315.0	59.0	213.00	21.9	36.9	–	–	3.3	30.00	950.00	0.210	–

Explanations:
– no information.

material. The EU directive requires testing for the presence of chemical compounds “occurring” in the environment, such as microplastics that can leach into the bottled water from the retail packaging [41–43].

The results of the present study were compared with the findings reported by other researchers. The content of microelements in mineral water was discussed by, for example, Islam et al. [44], Kis and Baciu [45] and van der Aa [37]. Opoka et al. [46] studied the content of trace elements in popular mineral and medicinal waters produced in southern Poland using electrochemical methods. They reported the following concentrations: Zn – from 0.034 to 0.036 mg dm^{-3}, Cu – from 0.085 to 0.015 mg dm^{-3}, Cl^- – from 2.8 to 2,433.63 mg dm^{-3}, F – from 0.4 to 1.66 mg dm^{-3} and Ca – from 11.05 to 478.48 mg dm^{-3}. Other research papers indicate that Sr and Mn are most prevalent among the microelements in carbon mineral waters in Russia [47]. The concentrations of 69 elements in Bulgarian mineral waters were analysed by Lyubomirova et al. [48]. These authors tested 17 Bulgarian and 8 imported brands of mineral water bought in a Bulgarian chain store. They found that in the case of several brands As, Fe, Hg and Na concentrations exceeded

Table 5
Concentration of selected bioelements in bottled mineral waters

Elements	Al	As	Ba	Br	Co	Cr	Cu	Ge	I	Mn	Ni	P	Rb	Se	Sr	Ti	Zn
Numbers of bottled waterbottled water[a]								Concentration (mg dm^{-3})									
1			2.20E+03					1.03E+00					1.90E+01		1.80E+03		1.05E+01
2	3.76E+02		2.47E+01	2.33E+01		1.39E+00	1.01E+00					7.48E+02	5.08E+00		1.52E+03		5.35E+00
3														5.13E-01			
4		1.42E+00	2.86E+02	1.77E+01			1.07E+00						1.39E+00		2.45E+02		7.42E+01
5			1.09E+02	1.26E+01		5.25E+00	6.30E-01			8.00E-01					3.39E+02		3.61E+00
6														9.30E-02			
7	8.03E+03		4.52E+03	1.24E+04				5.36E+01	1.63E+03	1.15E+02		3.04E+03	3.86E+02		1.81E+03		6.48E+01
8														2.50E-01			
9	8.52E+03		1.76E+03	2.98E+03			9.51E+00	1.77E+01	5.81E+02	1.70E+02	7.22E+00	1.71E+03	1.26E+02		7.05E+02		4.16E+01
10	4.73E+02		2.14E+02	1.86E+01	7.12E+00					4.54E+02	2.05E+01	5.61E+02	2.72E+00		5.15E+02		8.08E+00
11			7.75E+01	4.06E+01			8.10E-01						5.33E+00	4.22E-01	1.28E+03		5.17E+00
12			1.34E+02	9.42E+00		1.61E+00	8.10E-01			6.00E-01			5.41E-01	1.63E-01	3.30E+02		6.84E+00
13														5.00E-01			
14			9.90E+02	2.36E+01		3.72E+00	4.36E+00			1.32E+02			1.08E+01	4.47E-01	2.57E+03		6.73E+00
15														2.79E-01			
16	5.00E+02		1.24E+03	2.79E+01			1.91E+00			3.43E+02		1.24E+03	1.09E+01	4.95E-01	1.65E+03		1.13E+01
17														3.86E-01			
18	4.13E+02		2.03E+01	3.83E+01		1.86E+00	1.06E+00						4.43E+00	4.98E-01	2.29E+03		3.89E+00
19			1.92E+01	8.69E+01		4.77E+00	2.77E+00					9.56E+02		5.60E-01	5.67E+02	1.27E+01	6.98E+00
20														1.50E-01			
21			1.06E+03	4.50E+01			1.37E+00			1.70E+02			1.90E+01		8.03E+02		1.00E+01
22			1.70E+01	1.46E+01		6.20E-01	4.60E-01			6.50E-01			3.14E+00		3.03E+02		2.94E+00
23			3.96E+01	2.35E+01		3.33E+00	3.35E+00						3.46E+00		4.38E+02	5.53E+00	1.47E+01
24		7.00E-01	1.13E+01	3.90E+02		8.31E+00	7.80E-01								2.52E+03		6.22E+00
25			4.83E+04	2.91E+01		1.02E+01	6.07E+00			2.96E+02			2.19E+01		1.66E+04		2.26E+01
26	1.59E+03		4.37E+02	1.16E+03				6.49E+00		4.47E+01			5.09E+01		4.68E+02		8.16E+00
27		1.28E+00	0.00E+00	2.16E+01	2.59E+00		1.20E+00			2.55E+02			1.75E+02		5.09E+02		6.88E+00
28			4.28E+02	1.53E+03			4.92E+00	7.04E+00		2.44E+02			7.58E+01		4.60E+02		1.14E+01
29	1.07E+04		1.51E+03	4.94E+03			0.00E+00						4.42E+02		1.65E+03		4.79E+01

[a]names of individual bottled waters at the request of the corresponding author.

Table 6
Calculation of daily doses of uptake substances (CDI) in bottled water for: Al, As, Cr, Cu, Mn, Ni, P

Element		Al		As		Co		Cr		Cu		Mn		Ni		P	
		a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
RDI[c]		5.7	20	0.04	0.15			0.01	0.035	0.4	0.9	60	210	0.1	0.35	500	700
CDI average calculated (mg kg^{-1} bw d^{-1}) Numbers of bottled water	1	1.26E+00	1.34E+01														
	2							4.65E-03	**4.96E-02**	3.94E-02	1.05E-01					2.92E+01	7.80E+01
	4			4.75E-03	5.07E-02					4.17E-02	1.11E-01						
	5							**1.76E-02**	**1.88E-01**	2.46E-02	6.56E-02	3.12E-02	8.33E-02				
	7	**2.69E+01**	**2.87E+02**									4.49E+00	1.20E+01			1.19E+02	3.17E+02
	9	**2.85E+01**	**3.04E+02**							3.71E-01	9.91E-01	6.64E+00	1.77E+01	2.41E-02	2.58E-01	6.67E+01	1.78E+02
	10					2.78E-01	7.42E-01					1.77E+01	4.73E+01	6.86E-02	**7.33E-01**	2.19E+01	5.85E+01
	11									3.16E-02	8.44E-02						
	12							5.38E-03	**5.75E-02**	3.16E-02	8.44E-02	2.34E-02	6.25E-02				
	14							**1.24E-02**	**1.33E-01**	1.70E-01	4.54E-01	5.16E+00	1.38E+01				
	16	1.67E+00	1.78E+01							7.45E-02	1.99E-01	1.34E+01	3.57E+01			4.84E+01	1.29E+02
	18	1.38E+00	1.48E+01					6.22E-03	**6.64E-02**	4.13E-02	1.10E-01						
	19							**1.59E-02**	**1.70E-01**	1.08E-01	2.89E-01					3.73E+01	9.96E+01
	21									5.34E-02	1.43E-01	6.63E+00	1.77E+01				
	22							2.07E-03	2.21E-02	1.79E-02	4.79E-02	2.54E-02	6.77E-02				
	23							**1.11E-02**	**1.19E-01**	1.31E-01	3.49E-01						
	24			2.34E-03	2.50E-02			**2.78E-02**	**2.97E-01**	3.04E-02	8.13E-02						
	25							**3.41E-02**	**3.64E-01**	2.37E-01	6.32E-01	1.15E+01	3.08E+01				
	26	5.31E+00	**5.67E+01**									1.74E+00	4.65E+00				
	27			4.28E-03	4.57E-02	1.01E-01	2.70E-01			4.68E-02	1.25E-01	9.96E+00	2.66E+01				
	28									1.92E-01	5.13E-01	9.50E+00	2.54E+01				
	29	**3.57E+01**	**3.81E+02**														

Explanations:
[a]for children (bw = 20 kg);
[b]for adults (bw = 70 kg);
[c]RDI - recommended daily intake [29];
bold – exceeding the RDI.

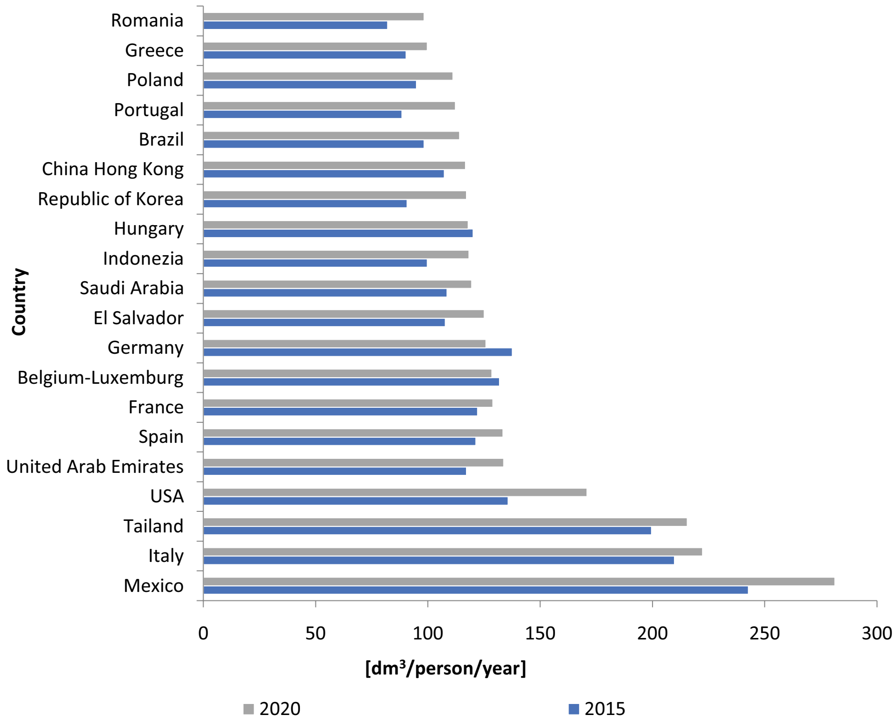


Fig. 5. Average annual consumption of bottled water for selected countries of the world (including Poland) in liters per person in 2015 and 2020. *Source*: [40].

Table 7
Description of the role of selected micronutrients on the human body

Element	Positive effect on the body	Negative effect on the body
Ni	affects the absorption of Fe and the functioning of the intestinal microflora [32]	mutagenic occupational exposure, genotoxic and carcinogenic effects, especially on the respiratory system
Mo	is involved in the metabolism of proteins and fats [17]	
Mn	influence on the structure of enzymes necessary for the metabolism of glucose and fatty acids, the functioning of the central nervous system [17,33]	
Se	trace element important for development. protection against oxidative stress of cells, deficiencies in supplementation may result in degenerative diseases [34]	toxic
Cu	enzyme component, effect on gene expression and the nervous system, effect on the production of red blood cells, on Fe transport. bone structure [17]	toxic in excess, disrupting the effects on the liver, nervous and immune systems, anemia
Cr	Provided with food in the form of Cr^{3+}, insulin receptor, RNA building block, effect on the metabolism of glucose and some proteins and fats metabolism [17]	excess may increase exposure to lung cancer, Cr^{6+} toxic, excess is mutagenic, occupational exposure, chromium deficiency may cause glucose intolerance [35]

the Bulgarian and/or European standards. The concentrations of selected micro- and macroelements in bottled water and ground water from the Carpathian Mountains in Romania were compared by Dippong et al. [49]. The study indicated that there exists a potential health hazard caused by Al^{3+}, Cl^- and NO_3^{2-}. A similar study on microelement concentrations (Cu, Zn, Fe, P, Ca, Mg, Mn, Mo, Co, As, Se, I, Br, and F) in potable water from wells was conducted by Sukharev et al. [50]. This study demonstrated a natural chemical composition of well water used as potable water in the Transcarpathian region in Ukraine. A characteristic property of this water was a relatively high concentration of Fe, ranging from 0.04 to 0.4 mg dm^{-3} (as a result the water had to be de-ironed before use) and a low concentration of Se, ranging from 0.009 to 0.0036 mg dm^{-3}. Similar concentrations of Se were found in the present study in the well water from southern Poland. These ranged from 0.00013 mg dm^{-3} (iii), through 0.00044 mg dm^{-3} (ix), to 0.00079 mg dm^{-3} (vi).

5. Conclusions

The present study yielded the following conclusions:

- water supplied to consumers has the characteristics of natural low-mineral spring water;
- the average total content of all elements in water from the water distribution system ranged from 0.15 mg dm^{-3} (WTPss) to 0.2 mg dm^{-3} (WTPs);
- the highest content of mineral salts in raw water was found in infiltration wells supplying water to WTPs (average 0.46 mg dm^{-3}, max 2.6 mg dm^{-3});
- as regards the microelements and ultratrace elements analysed, the quality of raw water in the Dunajec River in Świniarsko (iv) is not inferior to water in the Stary Sącz (vii) intake;
- water supplied to the public water distribution system has a uniform and stable chemical composition and contains microelements essential to the proper functioning of the human body;
- treated water supplied to the water distribution system provides 0.0001%–0.0003% of the recommended daily intake (RDI) for Al, As, Cd, Co, Cr, Cu, Mn, Mo, Ni, P, and Sn for children and for adults;
- all elements with a carcinogenic potential (Al, As, Cd, Cr, Ni) showed higher RDI coverage in adults than in children;
- among the non-carcinogenic parameters, the CDI for Mn, Mo and Sn was slightly higher in children in water supplied to the water distribution system;
- the mixing of river water (iv) with well water (iii and vi) at WTPs reduces the concentration of Cr in treated water supplied to the water distribution system (i and ii);
- bottled mineral water provides considerably higher doses of microelements than those stemming from the RDI;
- the doses of Al, Cr and Ni calculated for mineral water were 1 to 2 times higher than the RDI for children and 1.5 to 7 times higher than the RDI for adults;
- Al and Ni content was exceeded mainly in healing waters, and Cr in moderately mineralized waters;
- the doses of carcinogenic and potentially carcinogenic parameters are of particular importance. It was found that the average concentration of As in bottled waters provided 9% RDI for children and 27% for adults, Cr: 37% RDI and Ni: 46% for adults.
- consumers should be careful about drinking water with high concentration of microelements – not every mineral water is suitable for daily consumption;
- while the consumption of bottled water around the world is rising, some European countries are witnessing its decline, which might suggest a new trend for increased consumption of water from distribution systems – "straight from the tap" – whose chemical composition is similar to that of low-mineral water.

Author contributions

Conceptualization, A.K. and E.W.; Methodology, A.K.I.W. and E.W.; Formal Analysis, A.K. and E.W.; Data Curation, E.W.I.W.; Writing-Original Draft Preparation E.W., A.K. and I.W.; Writing-Review & Editing, A.K. and E.W.; Visualization, I.W. and E.W.; All authors have read and agreed to the published version of the manuscript. EW – 50%, A.K – 25%, I.W. – 25%.

Conflicts of interest

The authors declare no conflict of interest.

Funding

This research was financially support by the Polish Ministry of Science and Higher Education (grant No. 0033/DW/2018/02) and by AGH-UST (grant No.16.16.140.315).

Conflict of interest

The authors declare no conflict of interest.

References

[1] J.-P. Chouraqui, S.N. Thornton, L. Seconda, S.A. Kavouras, Total water intake and its contributors in infants and young children, Br. J. Nutr., (2021) 1–11, doi: doi: 10.1017/S0007114521003469.

[2] H. Szajewska, P. Socha, A. Horvath, Principles of Nutrition of Healthy Infants, Recommendations of the Polish Society of Gastroenterology, Hepatology and Nutrition of Children, Stand. Med. Ped., 11 (2014) 321–338 (in Polish).

[3] European Food Safety Authority (EFSA), Scientific Opinion on Dietary Reference Values for Water, EFSA Panel on Dietetic Products, Nutrition, and Allergies (NDA), EFSA J., 2010.

[4] Word Health Organization, Nutrients in Drinking Water, 2005.

[5] H. Alidadi, S. Belin Tavakoly Sany, B.Z. Garaati Oftadeh, T. Mohamad, H. Shamszade, M. Fakhari, Health risk assessments of arsenic and toxic heavy metal exposure in drinking water in northeast Iran, Environ. Health Preventative Med., 24 (2019), doi: 10.1186/s12199-019-0812-x.

[6] A. Kicińska, E. Wysowska, Health risk related to the presence of metals in drinking water from different types of sources, Water Environ. J., 35 (2021) 24–40.

[7] S.S. Kullara, K. Shao, C. Surette, D. Foucher, D. Mergler, P. Cormier, D.C. Bellinger, B. Barbeau, S. Sauvé, M.F. Bouchard, A benchmark concentration analysis for manganese in drinking water and IQ deficits in children, Environ. Int., 130 (2019) 104889, doi: 10.1016/j.envint.2019.05.083.

[8] S. Akmroth, M. Mohale, M.C. Latham, Unnecessary water supplementation for babies: grandmothers blame clinics, Acta Pediatr., 89 (2000) 1408–1413.

[9] A. Rudnicka, K.K. Hozyasz, Practical aspects of water selection in the nutrition of healthy infants and healthy children, Pediatr. Med. Rodz., 14 (2018) 33–46 (in Polish).

[10] J.M. Balbus, M.E. Lang, Is the water safe for my baby?, Pediatr. Clin. North America, 48 (2001) 1129–1152.

[11] Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the Quality of Water Intended for Human Consumption. Available at: http://data.europa.eu/eli/dir/2020/2184/oj (Access: August 25, 2021).

[12] Directive (EU) 2009/54/EC of the European Parliament and of the Council of 18 June 2009 on the Exploitation and Marketing of Natural Mineral Waters. Available at: https://eur-lex.europa.eu (Access: January 25, 2022).

[13] Directive (EU) 2001/83/EC of the European Parliament and of the Council of 6 November 2001 on the Community Code Relating

to Medicinal Products for Human Use. Available at: https://sip.lex.pl/akty-prawne/dzienniki-UE/dyrektywa-2001–83 (Access: January 25, 2022).
[14] O.M. Roșca, T. Dippong, M. Marian, C. Mihali, L. Mihalescu, M.-A. Hoaghia, M. Jelea, Impact of anthropogenic activities on water quality parameters of glacial lakes from Rodnei mountains, Romania, Environ. Res., 182 (2020) 109136, doi: 10.1016/j.envres.2020.109136.
[15] T. Dippong, C. Mihali, D. Năsui, Z. Berinde, C. Butean, Assessment of water physicochemical parameters in the Strîmtori-Firiza Reservoir in Northwest Romania, Water Environ. Res., 90 (2018) 220–233.
[16] S.A. Navarro Silvera, T.E. Rohan, Trace elements and cancer risk: a review of the epidemiologic evidence, Cancer Causes Control, 18 (2007) 7–27.
[17] M. Derkowska-Sitarz, A. Adamczyk-Lorenc, The effect of minerals dissolved in drinking water on the human body, Scientific Works of the Mining Institute of the Wrocław University of Technology, 123 (2008) 39–48 (in Polish).
[18] T. Wojtaszek, Mineral water as a factor of ecological health prophylaxis, J. Element., 11 (2006) 399–409 (in Polish).
[19] T.O. Berner, M.M. Murphy, R. Slesinski, Determining the safety of chromium tripicolinate for addition to foods as a nutrient supplement, Food Chem. Toxicol., 42 (2004) 1029–1042.
[20] A. Chorostyński, A. Łach, G. Pasztyła, Physicochemical parameters and bacteriology of the discovered mineral and sulphide waters in the vicinity of Sanok and Lesko, and the possibility of therapeutic use of these waters, Acta Sci. Pol. Formatio Circumiectus, 17 (2018) 113–126 (in Polish).
[21] B. Nihlgård, I. Rosborg, M. Ferrante, Mineral Composition of Drinking Water and Daily Uptake, I. Rosborg, F. Kozisek, Eds., Drinking Water Minerals and Mineral Balanc, Springer, Cham, 2020.
[22] S.M. Rybicki, I. Wiewiórska, Minimization of aluminum concentration in tap water subjected to the coagulation process, Chem. Ind., 96 (2017) 1719–1722 (in Polish).
[23] US EPA, Risk Assessment Guidance for Superfund, Vol. 1: Human Health Evaluation Manual. Part B. Development of Risk-based Preliminary Remediation Goals. Interim. EPA/540R-92/003. Publication 9285.7-01B. Washington, DC. USA: Office of Emergency and Remedial Response, 1991. Available at: https://epa-prgs.ornl.gov/radionuclides/HHEMB.pdf
[24] US EPA, Exposure Factors Handbook, (2011) edition (EPA/600/R-09/052F).
[25] IARC Human Carcinogenic Hazard Identification List. Available at: https://monographs.iarc.who.int/list-of-classifications (Access on 15/03/2022).
[26] E. Wiśniowska, M. Włodarczyk-Makuła, J.R. Rak, B. Tchórzewska-Cieślak, Estimation of potential health and environmental risk associated with the presence of micropollutants in water intakes located in rural areas, Desal. Water Treat., 199 (2020) 339–351.
[27] US EPA, Integrated Risk Information System (IRIS), 2005. Available at: www.epa.gov/iris
[28] US EPA, Concepts, Methods and Data Sources for Cumulative Health Risk Assessment of Multiple Chemicals, Exposures and Effects: A Resource Document, EPA/600/R-06/013F Washington (DC), Cincinnati: National Center for Environmental Assessment, Office of Research and Development, 2007.
[29] A. Kicińska, P. Glichowska, M. Mamak, Micro- and macroelement contents in the liver of farm and wild animals and the health risks involved in liver consumption, Environ. Monit. Assess., 191 (2019) 132, doi: 10.1007/s10661-019-7274-x.
[30] J. Ciuła, Modelling the migration of anthropogenic pollution from active municipal landfill in groundwaters, Arch. Civ. Eng., 14 (2021) 81–90.
[31] E. Wysowska, I. Wiewiórska, A. Kicińska, The impact of different stages of water treatment process on the number of selected bacteria, Water Resour. Ind., 26 (2021) 100167, doi: 10.1016/j.wri.2021.100167.
[32] B. Zambelli, S. Ciurli, Nickel and human health, Met. Ions Life Sci., 13 (2013) 321–357.
[33] D.S. Avila, R.L. Puntel, M. Aschner, Manganese in health and disease, Met. Ions Life Sci., 13 (2013) 199–227.
[34] M. Kieliszek, Selenium–fascinating microelement, properties and sources in food, Molecules, 24 (2019) 1298, doi: 10.3390/molecules24071298.
[35] A. Piotrowska, W. Pilch, Ł. Tota, G. Nowak, The biological importance of chromium III for the human body, Occup. Med., 69 (2018) 211–223.
[36] M. Wilhelm, U. Ewers, C. Schulz, Revised and new reference values for some trace elements in blood and urine for human biomonitoring in environmental medicine, Int. J. Hyg. Environ. Health, 207 (2004) 69–73.
[37] M. van der Aa, Classification of mineral water types and comparison with drinking water standards, Environ. Geol., 44 (2003) 554–563.
[38] G.S. Sarla, Is bottled water better than tap water?, Res. Rev.: J. Toxicol., 10 (2020) 30–33.
[39] M.F. Doria, Bottled water versus tap water: understanding consumers' preferences, J. Water Health, 4 (2006) 271–276.
[40] https://bottledwater.org/wp-content/uploads/2021/07/2020BWstats_BMC_pub2021BWR.pdf (Access on 03/09/2021).
[41] R.S. Garcıa, A.S. Silva, I. Cooper, R. Franz, P.P. Losada, Revision of analytical strategies to evaluate different migrants from food packaging materials, Trends Food Sci. Technol., 17 (2006).
[42] A.S. Silva, C.R. Franz, P.P. Losada, Compilation of analytical methods and guidelines for the determination of selected model migrants from plastic packaging, Trends Food Sci. Technol., 17 (2006) 535–546.
[43] J. Ciuła, V. Kozik, A. Generowicz, K. Gaska, A. Bak, M. Paździor, K. Barbusiński, Emission and neutralization of methane from a municipal landfill-parametric analysis, Energies, 13 (2020) 6254, doi: 10.3390/en13236254.
[44] R. Islam, S. Md. Faysal, Md. R. Amin, F.M. Juliana, M.J. Islam, Md. J. Alam, M.N. Hossain, M. Asaduzzaman, Assessment of pH and total dissolved substances (TDS) in the commercially available bottled drinking water, IOSR J. Nurs. Health Sci. (IOSR-JNHS), 6 (2017) 35–40.
[45] B.M. Kis, C. Baciu, The mineral waters from the Eastern Carpathians: a chemical review, Studia UbbAmbientum, Lix, 1–2 (2014) 71–80.
[46] W. Opoka, M. Szlósarczyk, A. Maślanka, J. Rojowski, K. Stopa, I. Borkowska, B. Muszyńska, M. Tyszka-Czochara, Some micro- and trace elements in selected bottled natural waters from the Polish market evaluated by electrochemical methods, J. Elementol., 22 (2017) 463–474.
[47] E.G. Kalitina, N.A. Kharitonova, T.V. Kuzmina, G.A. Chelnokov, Microorganisms in the Deposits of Cold Carbon Mineral Waters of the Russian Far East and Their Habitats, IOP Conference Series: Earth and Environmental Science, Vol. 115, All-Russian Research-to-Practice Conference "Ecology and Safety in the Technosphere" 6–7 March 2017, Yurga, Russian Federation Citation, 2018.
[48] V. Lyubomirova, V. Mihaylova, R. Djingova, Chemical characterization of Bulgarian bottled mineral waters, J. Food Compos. Anal., 93 (2020) 103595, doi: 10.1016/j.jfca.2020.103595.
[49] T. Dippong, M.-A. Hoaghia, C. Mihali, E. Cical, M. Calugaru, Human health risk assessment of some bottled waters from Romania, Environ. Pollut., 267 (2020) 115409, doi: 10.1016/j.envpol.2020.115409.
[50] S. Sukharev, L. Bugyna, O. Pallah (Sarvash), T. Sukhareva (Riabukhina), V. Drobnych, K. Yerem, Screening of the microelements composition of drinking well water of Transcarpathian region, Ukraine, Heliyon, 6 (2020) e03535, doi: 10.1016/j.heliyon.2020.e03535.