

OLIGOCENE AND BOTTLED WATER AS A SOURCE OF SODIUM IN EVERYDAY DIET OF ADULTS

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The aim of the study was to determine Oligocene and bottled drinking water as a source of sodium in everyday diets of adults.

Average sodium concentration in Oligocene water samples was 118 mg/L. Sodium intake with water, estimated for the average Oligocene water consumption, amounted to 132 mg/day (7% of maximal recommended sodium intake). For the part of population with the highest Oligocene water consumption (above 90th percentile), average daily sodium intake amounted to 220 mg and in the group consuming Oligocene water with the highest sodium concentration – to 285 mg (11% and 14% of the maximum recommended sodium intake, respectively).

An average bottled water consumption was about 0.46 L/day (among consumers of this water), and 1.24 L/day among persons with the highest bottled water consumption (intake above 90th percentile). Because average sodium concentration in bottled drinking water was related to the level of mineralization (5–148 mg/L), daily sodium intake amounted to 2–68 mg in all bottled drinking water consumers, and to 6–184 mg/day among persons with water intake above 90th percentile.

The results obtained support the claim that consumption of sodium with Oligocene and bottled drinking water should be considered a significant source of this element in a daily human diet.

INTRODUCTION

Sodium is a widespread element in nature and as a consequence in food products and in drinking water. It is present mainly in a form of sodium chloride, especially in processed food [Ziemiański *et al.*, 1998; Barylko-Pikielna & Jawor-Kulesza, 1993]. Water may be an important source of minerals such magnesium, calcium, fluoride and sodium also [Pietruszka & Rybarczyk, 2004; Garzon & Eisenberg, 1998]. Sodium concentration in potable water should not exceed 200 mg/L according to WHO guidelines of 1993 [WHO's drinking water..., 1993] and EC Directive of 1998 [EU's drinking water..., 1998].

Although the main source of drinking water for towns' inhabitants is tap water many of consumers use bottled water [Śmiegiel-Papińska *et al.*, 2001; Pietruszka & Zielińska, 2000], and Oligocene groundwater, for example in Warsaw [Pietruszka & Rybarczyk, 2004].

Contrary to heavily polluted surface waters, Quaternary and Tertiary groundwater, and Oligocene groundwater in particular, are assessed as of good or moderate quality [Environmental Protection Programme ..., 2004; Latour, 1996]. Usually groundwater abstracted from Oligocene level is assessed as suitable for drinking purpose without preliminary treatment or after reduction of iron and manganese concentration [Environmental Protection Programme ..., 2004; Latour, 1996; Dowgiałło & Macioszczyk, 1997]. Increased salinity of

Oligocene groundwater occurring sporadically is usually of spot character, and most often takes place due to technological drawbacks of the boreholes or due to abandonment of unused wells [Dowgiałło & Macioszczyk, 1997]. Increased salinity may also be a result of natural mixing of groundwater from two levels: Oligocene and Miocene [Environmental Protection Programme..., 2004; Dowgiałło & Macioszczyk, 1997].

Requirements regarding bottled drinking water quality are stipulated in EU Directives [EU's drinking water..., 1998] and waters with sodium concentrations < 20 mg/dm³ may be labeled as a "low-sodium" product. Bottled water is properly labeled both in Poland and in the world (nutritional label). However, due to substantial competition on the market consumers may experience problems with selection of the most suitable product [van der Aa, 2003]. In addition, numerous consumers do not pay their attention to the information contained in the food labels [Śmiegiel-Papińska *et al.*, 2001].

Sodium plays a vital role in water-electrolytic balance in organism, in maintaining of extracellular spaces' volume, in regulation of acid-base balance [Barylko-Pikielna & Jawor-Kulesza, 1993; Ziemiański, 2001; Dietary Reference..., 2004]. Its shortage, which may occur for example at people working physically in high temperatures or in anorexia, may lead to serious deterioration of health as a result of impairment of cells' functions, in particular muscle and nervous cells. Excessive sodium intake, which is a common problem in developed

countries, may in many cases result in increased blood pressure levels, which is a risk factor of cardiovascular and kidneys diseases [Antonios & MacGregor, 1996; Kaplan, 2000]. Some results indicate that an increase of blood pressure may occur in infants and children drinking water rich in sodium, and milk mixtures prepared with such water [Pomeranz *et al.*, 2002]. Therefore it is recommended that children get water with low sodium concentration [Rudzka-Kańtoch & Weker, 2000]. A relation between sodium (sodium chloride) intake and occurrence of stomach cancer and stroke has also been confirmed [Baryłko-Pikielna & Jawor-Kulesza, 1993; Antonios & MacGregor, 1996; McGregor, 1997]. Excessive sodium intake results also in an increased loss of calcium with urine, which may lead to excessive decrease of bone density. It is of significant importance for elderly people and women in menopausal age being at risk of osteoporosis [McGregor, 1997].

The health effect of water depends not only on cations' content but also on the type of dissolved anions. For example, sodium in a form of NaCl results in increased calcium elimination with urine, while such effect is not caused by NaHCO₃ [Luft *et al.*, 1990]. It was proven that individuals consuming 1 L/day of water rich in sodium, bicarbonate ions and chloride ions have, in comparison with individuals consuming low-mineralized water, are characterised by a decreased general cholesterol level, decreased LDL fraction level and increased HDL fraction level [Schoppen *et al.*, 2004]. Intake guidelines (Adequate Intake – AI) for sodium vary depending on age and physical activity of an individual. For younger adults the recommended sodium intake is 1.5 g/day (65 mmol), for older adults and older males it accounts for 1.3 g/day, whereas for women aged above 70 years – for 1.2 g/day (50 mmol) [Dietary Reference Intake, 2004]. According to Polish guidelines, the minimum daily intake for adults should be 500–625 mg, depending on sex, age and physical activity [Ziemlański, 2001]. According to WHO experts, daily intake of sodium should not exceed 2000 mg/day (which equals to 5 g of table salt) [Report of the Joint..., 2002].

Research on sodium intake indicates its excessive content in a diet, both in Poland [Baryłko-Pikielna & Jawor-Kulesza, 1993] and abroad [Mensink *et al.*, 2002; Kim *et al.*, 2005]. Average table salt intake in Poland amounts to 15 g daily [Central Statistical Office, 2004].

It has lately been observed that bottled water consumption has a strong tendency to increase. Results of a study conducted in 1990s indicated that only *ca.* 4% of adult respondents consumed bottled drinking water [Pietruszka & Zielńska, 2000], while in 2001 *ca.* 70% of adults reported to have a habit of drinking such water [Śmigiel-Papińska *et al.*, 2001]. Similar results - above 70% of adolescents consuming bottled water - were published in 2002 [Pietruszka *et al.*, 2002]. Growth of production and consumption of bottled drinking water in Poland [Kucharski, 2002] indicate the need to conduct survey on water as a source of minerals, including sodium.

It has rarely been taken into account that water may be a significant source of sodium and other elements important from the dietary point of view [Latour, 1996; Dowgiałło & Macioszczyk, 1997]. An attempt was also made to assess average sodium intake associated with Oligocene and bottled

drinking water consumption and the share of water in supply of sodium with a daily diet, which would complete previously published results concerning the share of Oligocene water in coverage of daily dietary recommendation [Pietruszka & Rybarczyk, 2004].

The aim of the investigation was to determine sodium intake contained in Oligocene and bottled drinking water among adult consumers of water in relation to dietary guidelines.

MATERIALS AND METHODS

The survey was conducted in two parts and was regarded as a pilot study of water as a source of sodium. The first part was connected with the assessment of Oligocene water consumption among adults in Warsaw, and the second one – bottled drinking water consumption among adults in Central Poland.

Determination of sodium content in Oligocene water samples. Oligocene water samples were collected in the period of May-June 2001, from 40 public access groundwater wells in Warsaw. Water samples were collected from each of the ground water abstraction wells in afternoon hours, into two polystyrene bottles previously etched with 10% HNO₃. Collected water samples were acidified with the use of HNO₃ in the amount of 0.5 mL for each 100 mL of water and were stored until the time of analysis at a temperature of -4°C. Sodium concentration in water samples was determined with the use of Flame Atomic Absorption Spectroscopy instrument SOLAAR Unicam 98 [Solar Methods Manual, 1997]. The result was given as an average value of three determinations. As a reference material, water SRM1643d was used. The value measured for sodium was 96.6% to declared reference values.

Estimation of sodium content in bottled drinking water. Information about sodium content in bottled water was delivered on the basis of analyses of the Polish market in the years 2001–2002. One hundred and twenty bottled water labels were collected. In respect of total minerals content each product was classified to one of three groups: (i) low level of mineralization – <500 mg/L; (ii) medium level of mineralization – 500–1500 mg/L; and (iii) high level of mineralization – > 1500 mg/L.

The average sodium content was assessed in each group separately.

Quantitative assessment of Oligocene water consumption. Quantitative assessment of Oligocene water consumption was conducted in 2001 in Warsaw, among adults. Out of 350 people, selected from every quarter of the city, 164 agreed to participate in the investigation, among them 114 women and 50 men, in the average age of 32 years. Data on Oligocene water consumption was obtained with the use of a questionnaire method. The questionnaire form included questions about making use of Oligocene groundwater abstraction wells, amount of water collected at a single time from the intake, amount of water used for cooking purpose: cooking of meals, soups, consumption of water in drinks, as a “raw” water and boiled water. Among all participants 55%

declared they make use of public access Oligocene groundwater abstraction wells on a regular basis. A detailed profile of respondents was presented in the previously published publication [Pietruszka & Rybarczyk, 2004].

Based on data obtained, the average daily consumption of Oligocene water was estimated for every respondent. The results were expressed as an average consumption and its range, for the entire examined population. Average theoretical sodium intake associated with Oligocene water consumption was calculated based on the amount of consumed water and determined sodium concentration in water. The results obtained were compared with guidelines for minimum and maximum sodium intake [Ziemiański, 2001; Report of the Joint..., 2002].

Quantitative assessment of bottled drinking water consumption. Quantitative assessment of bottled drinking water consumption was conducted in 2001–2002 in Mazovian and Lublinian district among 187 adults (127 women and 60 men). Data on bottled drinking water consumption was obtained with the use of a questionnaire method. The questionnaire form included questions on frequency and portion size of beverages consumption, among them bottled drinking water.

Statistical analysis of the results obtained was made with the use of Statistica PL v. 6.0 software. Due to the lack of normal distribution the results of average concentration of minerals in water were presented as median and quartiles.

RESULTS AND DISCUSSION

Sodium content in oligocenic and bottled water varies greatly, depending on the nature of the water well and/or the source of water in bottled product.

The results of the analysis revealed (Figure 1) highly variable concentrations of sodium in Oligocene water abstracted from particular wells, ranging from 5.9 mg/L to 170.7 mg/L, not exceeding in any case the recommended maximum amount of 200 mg/dm³ [WHO's drinking water..., 1993; EU's drink-

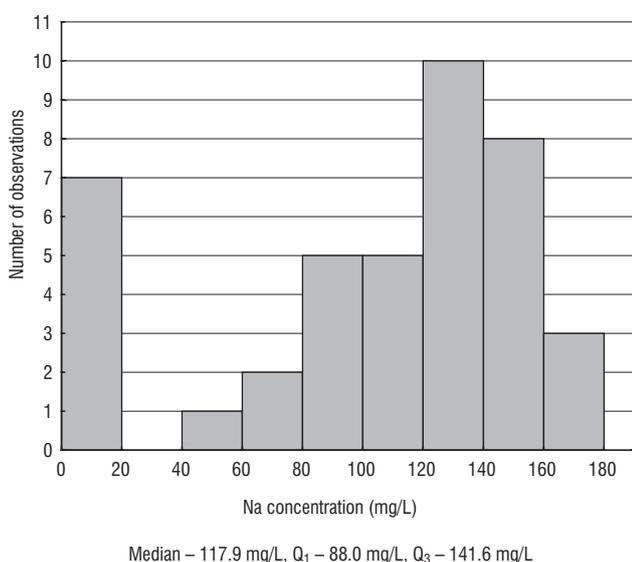


FIGURE 1. Distributions of sodium, concentration (mg/L) in Oligocene water samples.

ing water..., 1998; Minister of Health Decree, 2000]. Average sodium concentration was 118 mg/L, so it was relatively high. On the other hand, water samples from seven abstraction wells contained less than 20 mg/L of sodium (5.9–19.5%), which entitles to qualify them as low-sodium waters [van der Aa, 2003], recommended in a diet with lowered sodium content. The results of chemical analysis of Oligocene water abstracted from seven wells located at the outskirts of Warsaw (among others in the surroundings of Łomianki and Kampinos) were characterised by high variability of values of sodium content: from 9.3 mg/L to 299 mg/L, which is a value significantly exceeding guidelines, although in 3 cases sodium concentration was lower than 20 mg/L [Environmental Protection Programme..., 2004]. Differences in sodium concentration may result from both natural salinity and mixing of water from different groundwater levels, but also from technical errors committed during drilling and installation of the wells and their removal [Dowgiałło & Macioszczyk, 1997]. Sodium concentrations in the tap water in Warsaw also differ significantly in a wide range, depending on the characteristic of individual groundwater abstraction well. For example, water from the Central Water Supply System (*Wodociąg Centralny*) contained 156 mg/L, from the Northern Water Supply System (*Wodociąg Północny*) – 15.5 mg/L, and from Praski Water Supply System (*Wodociąg Praski*) – 100 mg/L [Perchuc, 1998]. Therefore, it was found that in some Oligocene water abstraction wells sodium concentration was higher than in the tap water.

Average sodium content in bottled drinking water (Figure 2) was dependent on the degree of mineralization of the water and was calculated at 148 mg/L for highly mineralized product, at 12.1 mg/L for medium-mineralized water and at 5 mg/L for waters with a low degree of mineralization. The amount of sodium intake is directly associated with the type of water selected by a consumer. Research conducted in Poland indicated that low-mineralized waters are preferred by the customers, thus the products contained lower average sodium concentration, however the concentrations of calcium and magnesium were respectively lower, too [Śmigiel-Papińska *et al.*, 2001]. In majority of cases the sodium content was lower than 200 mg/L and this value was never exceeded in the groups of low- and medium-mineralized waters. In the group of highly-mineralized waters this concentration was substantially higher in 13 cases (Figure 2). Some mineral waters produced and sold in Europe contain up to 1200 mg/L of sodium [Garzon *et al.*, 1998].

Information received from respondents was the basis of an estimate of an average consumption of oligocenic and bottled drinking water. Based on the information on frequency and amount of water and meals prepared on the basis of Oligocene water and consumed by respondents, it was estimated that the average daily Oligocene water consumption was 1120±600 g (the range of 105–3735 g). It was lower than the average consumption of tap water for consumption purpose, estimated by Gawęcki *et al.* [2001] at 1.4–1.5 L, and varied between 0.5 and 4 L/day [Śmigiel-Papińska *et al.*, 2001]. In addition, tap water consumption was higher in France and amounted to 1.6±1.7 L during the winter season and to 1.92±1.70 L during the summer season [Gofti-Laroche *et al.*, 2001].

In estimation of sodium intake with Oligocene water, two

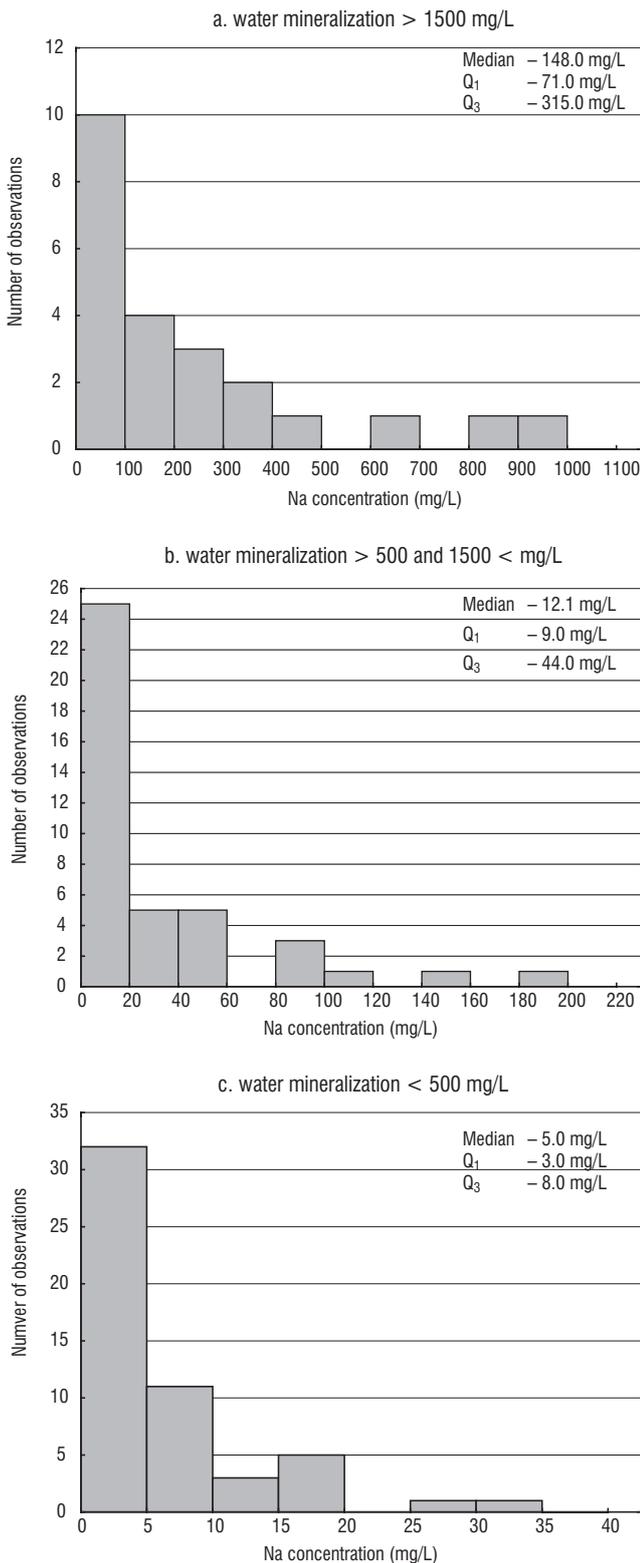


FIGURE 2. Distribution of sodium concentration (mg/L) in bottled drinking water samples.

levels of the consumption of water were taken into consideration: average daily consumption of Oligocene water for the whole population using public access wells and the population with the highest Oligocene water consumption (consumption above 90th percentile). It enabled to estimate what may be the highest potential intake of sodium, depending on its concentration in water (Table 1).

TABLE 1. Estimation of sodium intake with Oligocene water among consumers of this water in Warsaw.

Na concentration in Oligocene water samples		Sodium intake (mg) with Oligocene water (mean ± SD)	
Median for	mg/L	Total population (1.1±0.6 L water/day)	Persons with water intake > P90** (1.9±0.2 L water/day)
Total	117.9	132.0±70.7	221.7±24.8
Q1*	72.9	81.6±73.7	137.1±15.3
Q2	104.4	116.9±62.6	196.3±21.9
Q3	134.5	150.6±80.7	252.9±28.2
Q4	151.4	169.6±90.8	284.6±31.8
as % of the minimum recommended sodium intake (500–625 mg)			
Total	117.9	26.4±14.1 – 21.1±11.3	44.3±5.0 – 35.5±4.0
Q1*	72.9	16.3±14.7 – 13.1±11.8	27.4±3.1 – 21.9±2.4
Q2	104.4	23.4±12.5 – 18.7±10.0	39.3±4.4 – 31.4±3.5
Q3	134.5	30.1±16.1 – 24.1±12.9	50.6±5.6 – 40.5±4.5
Q4	151.4	33.9±18.2 – 27.1±14.5	56.9±6.4 – 45.5±5.1
as % of the maximum recommended sodium intake (2000 mg)			
Total	117.9	6.6±3.5	11.1±1.2
Q1*	72.9	4.1±3.7	6.9±0.8
Q2	104.4	5.8±3.1	9.8±1.1
Q3	134.5	7.5±4.0	12.6±1.4
Q4	151.4	8.5±4.5	14.2±1.6

* Q1, Q2, Q3, Q4 – quartiles; ** P90 – 90th percentile

Theoretical sodium intake, estimated for the average Oligocene water consumption, amounted to 132 mg/day and for 25% of the respondents it was higher than 170 mg (Q₄). Whereas for the part of population with high Oligocene water consumption (above 90th percentile), the average sodium intake amounted 220 mg and in the group consuming water with the highest sodium concentration (above 90th percentile) – 285 mg.

The contribution of Oligocene water in coverage of daily recommended allowances for sodium amounted to 7% on average. Although, taking into consideration a significantly higher than average consumption of Oligocene water by some people, the share of sodium contained in Oligocene water in coverage of recommended maximal daily sodium intake may amount to as much as 14%, and in coverage of the minimal daily sodium intake – to about 57% (Table 1).

Estimated average daily consumption of bottled water was 464±383 L/day, but in some cases it was much higher and reached 1.24±0.2 L/day (median P90) (Table 2). Theoretical sodium intake was calculated for each type of waters based on their mineralization degree and for the average and the highest daily water consumption rate. For an average water consumption rate the daily sodium intake ranged from 68 mg for highly mineralized product to 2.3 mg for the low-mineralized one. The same values for the highest level of daily water consumption were 184 mg and 6.2 mg, respectively.

The contribution of bottled water in coverage of recommended maximum daily sodium intake amounted to 3.5–0.1% in relation to mineralization level, and taking into

TABLE 2. Estimation of sodium intake with bottled drinking water among adult consumers of this water in relation of the mineralization level.

Na concentration in bottled drinking water		Sodium intake (mg) with bottled drinking water (mean \pm SD)	
Median for	mg/dL	Consumers of bottled water (0.46 \pm 0.38 L water/day)	Persons with water intake > P90** (1.24 \pm 0.2 L water/day)
High*	148.0	68.1 \pm 56.2	183.5 \pm 29.6
Medium*	12.1	5.6 \pm 4.6	15.0 \pm 2.4
Low*	5.0	2.3 \pm 1.9	6.2 \pm 1.0
as % of the minimum recommended sodium intake (500-625 mg)			
High	148.0	13.6 \pm 11.2 – 10.9 \pm 9.0	36.7 \pm 5.9 – 29.4 \pm 4.7
Medium	12.1	1.1 \pm 0.9 – 0.9 \pm 0.7	3.0 \pm 0.5 – 2.4 \pm 0.4
Low	5.0	0.5 \pm 0.4 – 0.4 \pm 0.3	1.2 \pm 0.2 – 1.0 \pm 0.2
as % of the maximum recommended sodium intake (2000 mg)			
High	148.0	3.4 \pm 2.8	9.2 \pm 1.5
Medium	12.1	0.3 \pm 0.2	0.8 \pm 0.1
Low	5.0	0.1 \pm 0.1	0.3 \pm 0.1

* the level of mineralization; ** P90 – 90th percentile

consideration the highest level of bottled water intake the same values were between 9–0.3% (Table 2). In coverage of the minimum daily sodium intake the values were about 14–0.5% and 37–1.2%, respectively.

Therefore, potable water may be assessed as a very significant source of this element, usually not taken into account in the assessment of daily sodium intake. Additionally, respondents of nutritional questionnaires frequently forget to report consumption of such beverages as coffee, milk and table water. Therefore, the actual water consumption may in fact be higher than reported [Ingwersen *et al.*, 2004]. In some cases, sodium content in water provides full coverage of recommended minimum daily allowances of intake of this element. In addition, other authors say that sodium content in potable water, in particular highly-mineralized, may be as high as half the recommended daily dose [Azoulay *et al.*, 2001].

Similarly, in the investigation conducted in Germany it was discovered that potable water is a significant source of sodium for the Germans. It is mentioned among seven most significant sources of sodium for men (after spices, bread, ham and sausages, milk products, meat and pastries) and six most significant sources for women (after spices, bread, ham and sausages, milk products and meat) [Mensink *et al.*, 2002].

CONCLUSIONS

1. Although in any of the analysed Oligocene water samples originating from different abstraction wells located in Warsaw an exceeding of maximum recommended concentration was noted, but still an average sodium concentration was relatively high, approximately 120 mg/L, which is a six times higher concentration than that described in the UE Directive as “usually occurring in potable water treated as low-sodium water” (20 mg/L).

2. Sodium content in bottled drinking water varies between 5–148 mg/L depending on the degree of mineralization of water; in case of low- and medium-mineralized water

products vast majority of them may be labeled as a “low-sodium product”.

3. Although the contribution of the Oligocene water in the maximum recommended daily sodium intake was only 7%, for some people it could have amounted to approximately 14% of the maximum recommended daily intake, which means that Oligocene water may be in some cases a significant source of sodium.

4. Average contribution of bottled water in fulfilling the daily recommended allowance of sodium is lower than in the case of oligocenian water consumption and ranges from 0.1% to 3.4% depending on the degree of mineralization of water and in the cases of particularly high consumption level (P90) it may reach from 0.3% to 9.2%.

5. Results of this study support the claim that consumption of sodium with Oligocene water and highly-mineralized bottled water should be considered a significant source of this element in a daily human diet. People with health problems related to the need of decreased sodium intake should pay particular attention to the fact that water is also a substantial source of sodium in their diet.

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WODY OLIGOCEŃSKA I BUTELKOWANE JAKO ŹRÓDŁO SODU W DIECIE OSÓB DOROSŁYCH

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Celem pracy była ocena wody oligoceńskiej i butelkowanych wód pitnych jako źródła sodu u osób dorosłych.

Średnie stężenie sodu w próbach wody oligoceńskiej wynosiło 118 mg/L. Oszacowane, na podstawie danych o ilości spożywanej wody oligoceńskiej, spożycie sodu z wodą wśród konsumentów tej wody wynosiło 132 mg/dzień (7% zalecanego maksymalnego spożycia). U części osób ze szczególnie wysokim spożyciem wody oligoceńskiej (powyżej 90-tego percentyla) średnie spożycie sodu wynosiło 220 mg/dzień, a u osób spożywających wodę o najwyższym stężeniu sodu – 285 mg (odpowiednio 11% i 14% maksymalnego zalecanego dziennego spożycia sodu), (tab. 1 i 2).

Średnie spożycie butelkowanych wód pitnych wśród konsumentów tej wody wynosiło około 0,46 L/dzień i u osób o najwyższym spożyciu tego typu napojów (90-ty percentyl) – 1,24 L. Zawartość sodu w butelkowanych wodach pitnych zależała od stopnia jej mineralizacji i wahała się od średnio 5 mg/L w wodach niskozmineralizowanych do 148 mg/L w wodach wysokozmineralizowanych. Dlatego też dzienne spożycie sodu z tego źródła może wahać się w zależności od rodzaju wybieranej wody od 2–68 mg sodu/dzień przy średnim spożyciu tej wody do 6–184 mg/dzień u osób o szczególnie dużym jej spożyciu.

Uzyskane wyniki wskazują, że oligoceńska i butelkowane wody pitne powinny być brane pod uwagę jako istotne źródło sodu w całodziennej racji pokarmowej.