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Evaluating the stability of iodine in bottled mineral waters

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ABSTRACT

The paper presents the results of a study aimed at fortifying mineral waters with iodine ions. In the study, natural mineral water with low CO_2 content was used, which had a high content of bioelements and minerals including calcium and magnesium and also included iodine concentrate and lemon flavour. Within the framework of the experiment, several water samples were prepared (1.5 L in volume each), which contained iodine concentrate (0.080 mg/L) and/or lemon flavour (0.5 mL). Additionally, analyses of control samples prepared using distilled water were carried out. In order to identify the changes in the composition of the analysed samples that were fortified with iodine, tests were performed immediately after the preparation of the samples and after 1 h, 4.5 h and 24 h. The results of the study showed a decrease in iodine content by 40% after 24 h. It was noted, however, that the decline in the content of iodides was 10% more rapid in samples of distilled water fortified with iodine than in samples of mineral water. Lemon flavour has a slight impact on the content of iodine determined, although these differences are in most cases statistically insignificant.

1. Introduction

Iodine plays an essential role in human metabolism and in the early development of most organs, including the brain (WHO, 2011). Iodine (atomic number 53) with an atomic weight of 126.9 is the heaviest stable member in group 17 of the periodic table (the halogens). In common with the other stable halogens (fluorine, chlorine and bromine), iodine forms a diatomic molecule, I_2. However, in contrast to the other halogens, elemental iodine exists as a solid which is volatile at room temperature. By gaining an electron to become I^-, iodine acquires an inert element structure. However, the first electron affinity of iodine being relatively low at −295 kJ/mol, I^- loses the acquired electron fairly easily being converted to I_2 (Fuge and Johnson, 2015).

Iodine is an essential element in the human diet and a deficiency can lead to a number of health outcomes collectively termed iodine deficiency disorders (IDD) (Fuge and Johnson, 2015). The daily requirement for this element in humans is approximately 150 μg (Knoch, 1991; Kabata-Pendias and Pendias, 1999; Kabata-Pendias and Szteke, 2012). Iodine deficiency may cause thyroid diseases (goitre symptoms and the related impairment of various metabolic functions – Selinus et al., 2005; WHO, 2011). In deficiency zones, iodine concentration in water typically ranges from 0.1 to 3 μg/L (Kabata-Pendias and Pendias, 1999; Witczak et al., 2013). Ensuring adequate iodine intake is important, particularly among women of reproductive age, because iodine is necessary for early life development. Biologically based dose–response modelling of the relationships among iodide status, perchlorate dose, and thyroid hormone production in pregnant women has indicated that iodide intake has a profound effect on the likelihood that exposure to goitrogens will produce hypothyroxinemia (Lewandowski et al., 2015).

Excess iodine concentrations are also harmful to humans, causing hyperthyroidism and a number of other adverse changes (Selinus et al., 2005). In large doses, far above its normal levels in waters, iodine can be toxic.

As a result of the dominant oceanic source, iodine is strongly enriched in near-coastal soils, but it has been suggested that inhalation represents a very minor source of iodine intake for humans and that even in coastal areas where atmospheric iodine is likely to be elevated, inhalation would provide only an estimated 5 mg/day (Risher and Keith, 2009). Human intake of iodine is mainly from food with some populations also obtaining appreciable quantities of iodine from drinking water (Fuge and Johnson, 2015).

Seafood provides major iodine-rich dietary items, but other inputs are mainly from adventitious sources, such as the use of iodised salt and from dairy produce, which is a rich source mainly due to cattle-feed being fortified with iodine, and to the use of iodine-containing sterilants in the dairy industry. High dietary salt is considered to be the cause of about 30% of hypertension cases among US adults (National Academy of Sciences, NAS, 2010). Globally, approximately one quarter of the adult population has hypertension, a leading risk factor for premature death. High salt intake is also linked to other diseases, including gastric cancer, obesity, kidney stones, and osteoporosis (Lewandowski et al., 2015).

Water is generally an insignificant source of dietary iodine; however, in some circumstances it can be a very major source (Risher and Keith,

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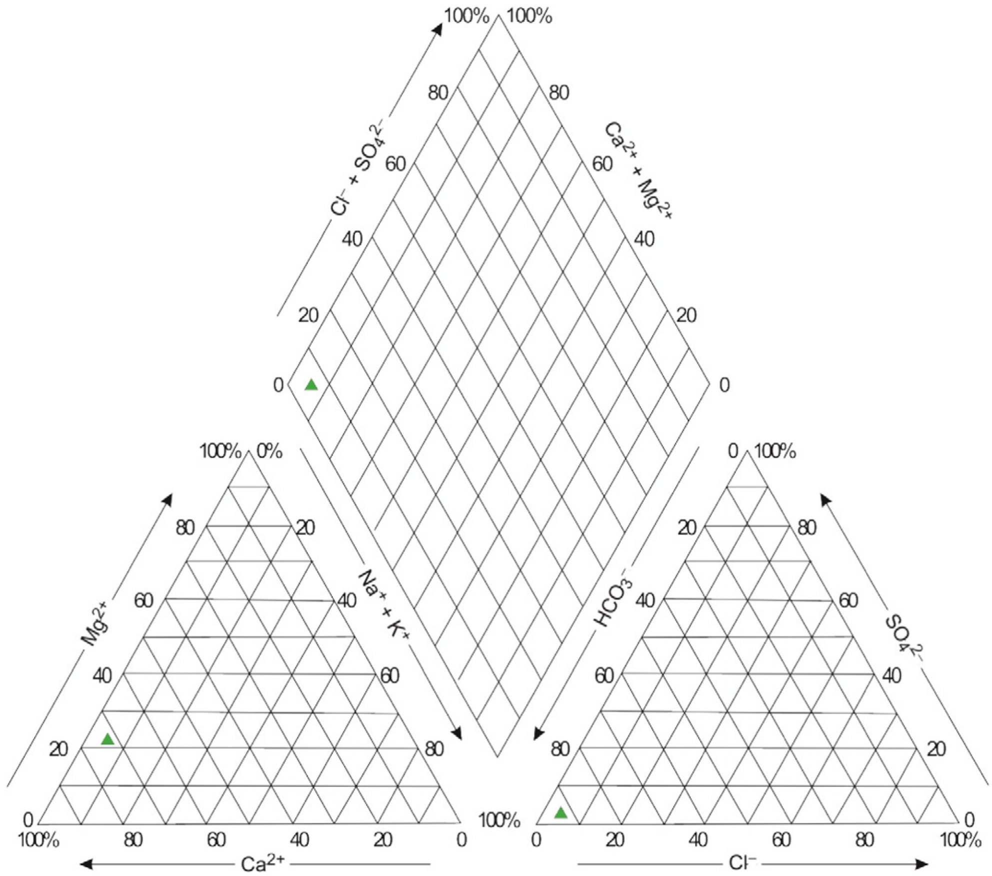

Fig. 1. Piper diagram of analysed water.

2009).Iodine concentrations in groundwater with low mineral content are generally very low – ranging from trace to 60 μg/L (Macioszczyk, 1987). Dojlido (1987) states that the range of iodide concentrations is from 4 to 13 μg/L for groundwater and from 1 to 20 μg/L for surface water. Polish, WHO, EU and U.S. regulations do not set permissible levels for iodine in drinking water (Witczak et al., 2013).

Iodine contents of up to 430 μg/L have been found to occur in the La Pampa Aquifer, Argentina (Smedley et al., 2002; Watts et al., 2010). According to Frengstad et al. (2010) bottled waters available for sale in the Nordic countries (22 products), which originate from Norway, Sweden, Finland and Iceland, contain iodide ions in concentrations ranging from 0.364 to 431 μg/L (with a median of 3.335 μg/L). On the other hand, tap water (18 measurements) had an iodine content ranging from 0.611 to 19 μg/L (with a median of 1.3 μg/L). Iodine concentrations of up to 1220 μg/L have been recorded in water from aquifers hosted by marine sediments in eastern Denmark (Voutchkova et al., 2014). Iodine-rich groundwaters have been found in several provinces of China (Wen et al., 2013), with iodine contents ranging up to 2800 μg/L in Jiangsu Province (Zhao et al., 2000) and up to 4100 μg/L in Shanxi Province (Tang et al., 2013). About half of the groundwater samples, either shallow or deep, contain >150 μg/L (Wen et al., 2013).

Lewandowski et al. (2015) suggested that the human health risks from supplementing drinking water with iodine are negligible; therefore, this approach is worthy of regulatory consideration. Thus it appears reasonable to consider the use of mineral water fortified with iodine as a source of easily assimilated iodine. Mineral water is characterised by its purity at source, its content in minerals, trace elements and other constituents, its storage and its medicinal properties (Petraccia et al., 2006; Ciężkowski et al., 2010). Mineral water can be put on the market and/or exploited for healing purposes (Petraccia et al., 2006).

As the trend towards a healthy lifestyle becomes increasingly popular, many mineral water brands are marketed in developed countries. The first functional water brands that are fortified with selected trace elements, vitamins, herbal extracts or probiotics have also begun to emerge. A significant development of this industry in world markets was observed from 2002 to 2008, mainly as a result of the scale of production and sales of such products in the United States and in Asia. Pioneers in the production and sale of functional water included the Coca-Cola and Pepsi-Cola brands, which were the first to introduce these new products to the U.S. market (ABC Consulting, 2013). In Eastern Europe, this sector is still developing. With growing public awareness of the role of healthy foods and, as a consequence, of the effects of consuming carbonated soft drinks, interest in the consumption of bottled table and mineral water has increased. In Poland, an increase in the sales of these products was observed particularly in the first years of the 21st century.

Table 1
Physical and chemical properties of mineral water tested (the results of the water quality provided by the producer).

Parameter	Concentration [mg/L]
TDS	1341.50
Na^+	17.55
K^+	3.35
Ca^{2+}	233.00
Mg^{2+}	44.08
Cl^-	17.30
SO_4^{2-}	24.60
HCO_3^-	961.3
I^-	<0.01
CO_2	500