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Review

Iodine and human health, the role of environmental geochemistry and diet, a review

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ABSTRACT

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). The geochemistry of iodine is dominated by its volatility with volatilisation of organo-iodine compounds and elemental iodine from biological and non-biological sources in the oceans being a major component of its global cycle. As a result of the dominant oceanic source, iodine is strongly enriched in near-coastal soils, however, the major zone of marine influence generally stretches to only 50–80 km inland and terrestrial sources of volatilised iodine, from wetlands, soils and plants are also an important aspect of its global geochemical cycle. Iodine in soils is strongly bound with transfer factors from soil to plants being generally small and as a consequence there is only limited uptake of iodine through the plant root system. It is likely that uptake of atmospheric iodine by the aerial parts of plants is an essential process and, along with iodine deposited on plant surfaces, is a major source for grazing animals. Human intake of iodine is mainly from food with some populations also obtaining appreciable quantities of iodine from drinking water. Plant-derived dietary iodine is generally insufficient as evidenced from the low dietary iodine of strict vegan diets. 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. While the distribution and geochemistry of iodine are reflected in the global distribution of IDD, the recent upsurge of IDD in developed countries would seem to reflect changes in diet.

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1. Introduction

Iodine has been known to be an essential element for humans since the middle of the 19th century, it being a constituent of the thyroid hormones triiodothyronine (molecular formula – $C_{15}H_{11}I_4NO_4$) and thyroxine (molecular formula – $C_{15}H_{12}I_3NO_4$). Historically, dietary iodine deficiency was synonymous with the disease of endemic goitre which according to Kelly and Sneddon (1960) affected almost every country prior to 1950. However, following the wide use of dietary iodine supplementation, in particular the use of iodised salt (e.g. Brush and Altland, 1952) and iodine supplementation of cattle-feeds, by the 1970s endemic goitre was virtually eradicated from the developed world, the disease subsequently being described by Gillie (1971) as “a disease of the poor”.

Further research highlighted the importance of iodine in foetal brain development with deficiency during foetal development resulting in irreversible brain impairment (Delange, 2000; Morreale de Escobar et al., 2004; Zimmermann, 2009), while it has been shown very recently that in the mildly iodine deficient UK, offspring of mothers who were iodine deficient in early pregnancy had lower than average IQ scores (Bath et al., 2013; Bath and Rayman, 2015). As a result it became apparent that iodine deficiency was manifested in health problems other than goitre and to this end Hetzel (1983) introduced the term iodine deficiency disorders (IDD) to cover all aspects of health outcomes resulting from dietary iodine deficiency. It is now generally accepted that damage to the brain resulting in mental retardation is the most significant effect of iodine deficiency (Li and Eastman, 2012) and, it has been suggested that iodine deficiency is one of the world's most common causes of preventable mental development problems ranging from sub-clinical minor IQ reduction to, in its worst form, cretinism (WHO, 2006).

Hetzel (1983) suggested that iodine deficiency could be eradicated within five years, however, while considerable strides have been made, Pearce et al. (2013) list thirty countries that are currently iodine deficient. Furthermore, while iodine deficiency had been presumed to be eradicated from the developed world, problems have re-emerged in many developed countries such as Australia, New Zealand and in several Western Europe countries. According to Andersson et al. (2012), globally almost 30% of schoolchildren have a suboptimum dietary iodine intake, while recent studies have highlighted mild iodine deficiency in pregnant females in the USA (Caldwell et al., 2013) and European countries (Trumpff et al., 2013), such as in Italy (Mian et al., 2009), Norway (Brantsæter et al., 2013), Portugal (Limbert et al., 2010) and the UK (Bath et al., 2013, 2014).

In view of its importance in human and animal health there has been considerable interest in the environmental geochemistry of iodine and its cycling through the biosphere. However, due to analytical constraints much of the early data on iodine geochemistry is somewhat suspect (Fuge, 1974). With the advent of new sensitive analytical methodologies for iodine, such as the use of ICP-MS (e.g. Tagami et al., 2006), more reliable data have been generated and as a result a great deal has been published on the various aspects of the geochemistry of iodine and its sources in human and animal diets.

In this paper the authors update a previous review of iodine geochemistry (Fuge and Johnson, 1986) and focus on the parts of the iodine geochemical cycle that are most important in the environmental controls on IDD. The behaviour and distribution of iodine in the environment is of significant interest in a range of scientific disciplines though the results of such studies are generally considered only within the specific area of interest. Here the results are applied to the wider context of the complete iodine cycle in the total environment.

In recent years, climate scientists have studied the generation and speciation of iodine in the atmosphere particularly with respect to its destruction of atmospheric ozone (Chameides and Davis, 1980; Solomon et al., 1994; Saiz-Lopez et al., 2012). In addition iodine oxides in the atmosphere have been linked with the formation of ultrafine particles which are important in cloud condensation (O'Dowd et al., 2002). It has also been suggested that in Arctic regions, the reactive species iodine oxide (IO) and atomic I are involved in atmospheric mercury depletion events where gaseous elemental mercury is converted to reactive mercury (Hg^{II}) which subsequently precipitates (Calvert and Lindberg, 2004; Saiz-Lopez et al., 2007b; Raofie et al., 2008; Auzmendi-Murua et al., 2014).

The harmful health effects of the radioactive isotopes of iodine, ^{131}I (half-life 8.07 days) and the long lived ^{129}I (half-life 1.7 × 10^7

Table 1
Iodine in some common rock types.

Rock type	Mean iodine content (mg kg^{-1})
Igneous rocks	
Granite	0.25
Other instrusives	0.22
Basalts	0.22
Other volcanics	0.24
Volcanic glasses	0.52
Sedimentary rocks	
Shale	2.3
Sandstone	0.8
Limestone	2.7
Organic-rich shales	16.7

From Fuge and Ander (1998).