Water Quality Fact Sheet:

Iodine

WHO guideline value (recommended limit): no recommended limit
Typical range in potable groundwater: <1 µg/l to 70 µg/l (extremes up to 400 µg/l)

This is one of a series of information sheets prepared for a limited number of inorganic constituents of significant health concern that are commonly found in groundwater. The sheets aim to explain the nature of the health risk, the origin and occurrence of the constituent in groundwater, the means of testing and available methods of mitigation. The purpose of the sheets is to provide guidance to WaterAid Country Office staff on targeting efforts for water-quality testing and to encourage further thinking within the organisation on water-quality issues.

Health effects

Most trace elements in drinking water are of concern from a public health point of view because of potential for excess above recommended limits. However, some trace elements are essential to health and so are required to be present at certain concentrations in drinking water or food. Iodine is one such essential element. Deficiency in dietary iodine can lead to a number of iodine-deficiency disorders (IDDs) in humans. No regulations or recommendations are placed on concentrations of iodine in drinking water because such standards are imposed to regulate upper rather than lower limits. Iodine may also be potentially detrimental to health at high concentrations, but the element usually behaves in a similar way to chlorine in nature and hence iodine-rich waters are likely to be rendered unfit for potable use due to high salinity before iodine becomes a significant problem.

Iodine is essential in human metabolism. It is instrumental in the production of thyroid hormones which are required for development and function of the nervous system and maintenance of body heat and energy (Dunn and Van der Haar, 1990). Dietary deficiency can result in a number of characteristic IDDs, the most common of which is goitre. This is an enlargement of the thyroid gland, caused by over-production of thyroid-stimulating hormones as compensation for the iodine deficiency. Chronic iodine deficiency can induce growth of goitres several inches across which may cause pain and discomfort due to restriction of blood supply and compression of the trachea and oesophagus and may also induce choking. Children and women of child-bearing age are particularly at risk. Other IDD symptoms include hypothyroidism (low blood-levels of thyroid hormone) which leads to lethargy, dry skin, intolerance to cold, growth- and mental-retardation and cretinism (severe mental retardation due to neo-natal hypothyroidism, which may also produce stunted growth and deaf-mutism). Inhibition of physical growth and mental development of children is a particular problem. IDDs have also been linked with high incidence of infant mortality and reproductive failure (Dunn and Van der Haar, 1990). They have also been held responsible for the impairment of economic development and quality of life and poor education prospects for millions of children and adults (Phillips et al., 1988). It is estimated that up to a billion people globally (around 19% of the world's population) are at risk from IDD. Around 200–300 million people have visible goitre or similar manifestations and around 6 million are cretins (Dunn and Van der Haar, 1990).

The daily iodine requirement of humans is about 100–200 µg. It has been estimated that the bulk of this (around 80%) is derived from food, the remainder from drinking water. Historically, IDDs have been identified in parts of most continents throughout the world. Today the problem tends to be mainly restricted to the poorer developing countries where diet is of limited nutritional quality and health education is poor. In populations taking an iodine-rich diet (notably dairy products, fish and meat), the iodine concentration of drinking water is relatively unimportant. It takes on an increased significance where diet does not provide the daily requirement. The distribution of iodine in the local environment (water, soils, rocks) is also important as it determines the ranges of iodine concentrations in locally-produced foodstuffs.

In areas prone to IDD, drinking waters with low iodine concentrations are commonly held responsible. McClendon and Williams (1923) suggested that concentrations of less than 3–5 µg/l iodine in drinking water were goitrogenic. Coble et al. (1968) found that in populations inhabiting Egyptian oases, drinking water with concentrations of 7–18 µg/l gave rise to goitre whilst concentrations of 44–100 µg/l did not. Wilson (1954) associated goitre incidence in Sri Lanka with drinking water iodine ranging between 1.4–2.7 µg/l. Mahedeva and Senthe Shanmuanathan (1967) found that goitrous areas in Sri Lanka had drinking-water iodine concentrations of 2.2–10.1 µg/l whilst non-goitrous areas had 19.4–183 µg/l. They defined the local critical iodine concentration as 10 µg/l. Smedley et al. (1995) found iodine concentrations in groundwaters from goitrous areas of the Upper East Region of Ghana in the range <1–10 µg/l (median 3.1 µg/l, most less than 6 µg/l). The ranges of concentrations identified as goitrous in these studies are quite variable and hence it is difficult to a assign a value below which further investigation should be made, but it seems that particularly vulnerable areas are where concentrations in the drinking water are typically 5 µg/l or less. Again however, it is stressed that prevalence of IDD relates not only to drinking water intake but to additional factors such as quality of nutrition.

Occurrence in groundwater

Iodine concentrations in groundwaters (and surface waters) largely lie in the range 0.01–70 µg/l, depending on geographical location and local geology and soils. Higher concentrations can be found in saline waters such as coastal and arid or semi-arid areas. The principal sources of iodine in groundwater are aquifers and soils and the atmosphere.

Iodine is found in low concentrations in most rocks because it is incompatible with most rock-forming (silicate) minerals. It may be present in higher concentrations in sulphide minerals, organic matter and iron oxides. Hence sulphide-, organic- and iron-rich rocks and soils tend to have the highest concentrations. Mineral veins (rich in sulphide minerals) and hydrothermal solutions are also relatively concentrated. Of the sedimentary rocks, muds and shales typically have the highest concentrations. Weathered rocks often have higher iodine concentrations than their pristine equivalents, presumably due to interaction with groundwater.

Iodine deficiency (goitre prevalence) has often been noted in people inhabiting limestone areas (e.g. Fuge, 1989). Until the turn of the century, goitre was endemic in north Derbyshire in the UK, being worst in areas where Carboniferous Limestone cropped out (Fuge and Long, 1989). The observed correlation has been linked with the occurrence of hard waters in such aquifers. Water 'hardness' is defined by the concentrations of calcium and magnesium present (hard waters having high concentrations). Since calcium and magnesium are suspected additional goitre-inducing factors, this may help to explain why goitre has been observed in some areas without notable iodine deficiency in local waters, rocks and soils. In such areas, iodine deficiency may also be induced by fixation of iodine by calcium in the soils, yielding low concentrations in groundwaters and decreased efficiency of uptake by plants (Fuge and Long, 1989).

The principal natural source of iodine is seawater (average value 58 µg/l). Iodine in rainfall in coastal areas is therefore generally higher than over continental areas and hence recharge of water to soils and aquifers will be higher in coastal areas. This correlates with the fact that goitre and related endemic disorders are often concentrated in inland areas remote from the sea (Figure 1). (Note though that IDDs have also been reported in some coastal areas with relatively high local water, soil and food iodine concentrations, e.g. Dissanayake and Chandrajith, 1993).

Goitre prevalence has frequently been reported in areas where soils are thin and organic-poor, the best examples being young mountainous areas, such as the Himalaya (Day and Powell-Jackson, 1972), Andes (Meyer et al., 1978) and the Alpine regions. Soil pH may also influence iodine release to groundwater: binding is stronger at low pH (less than around 5; Whitehead, 1973) and hence release may be less in acid conditions.

Iodine concentrations in drinking waters and soils are increased by man's activities. Iodine is used in herbicides, fungicides, dairy sterilants, detergents, table salt, pharmaceuticals and bread-making. It is also enhanced in the atmosphere from fossil-fuel combustion, car exhausts and sewage. Whitehead (1979) has suggested that surface waters draining industrialised and urban areas contain considerably more iodine than those draining rural areas.

Hence, studies suggest that considering geology alone, groundwaters in basement and limestone aquifers are the most likely to have low iodine concentrations. Considering geographical location, continental areas are more likely to be affected than coastal areas. Considering topographical variation, mountainous areas have a greater tendency to IDD prevalence than lowlands. Combination of these factors with additional nutritional factors greatly complicates the pattern of expected regional distributions. Nonetheless, whilst not necessarily being diagnostic of IDD risk in itself, analysis of iodine concentrations in groundwater from a given area will highlight potential areas with low iodine tendency, as concentrations in groundwater will inevitably reflect concentrations in local soils, rocks and food crops and hence overall dietary intake.

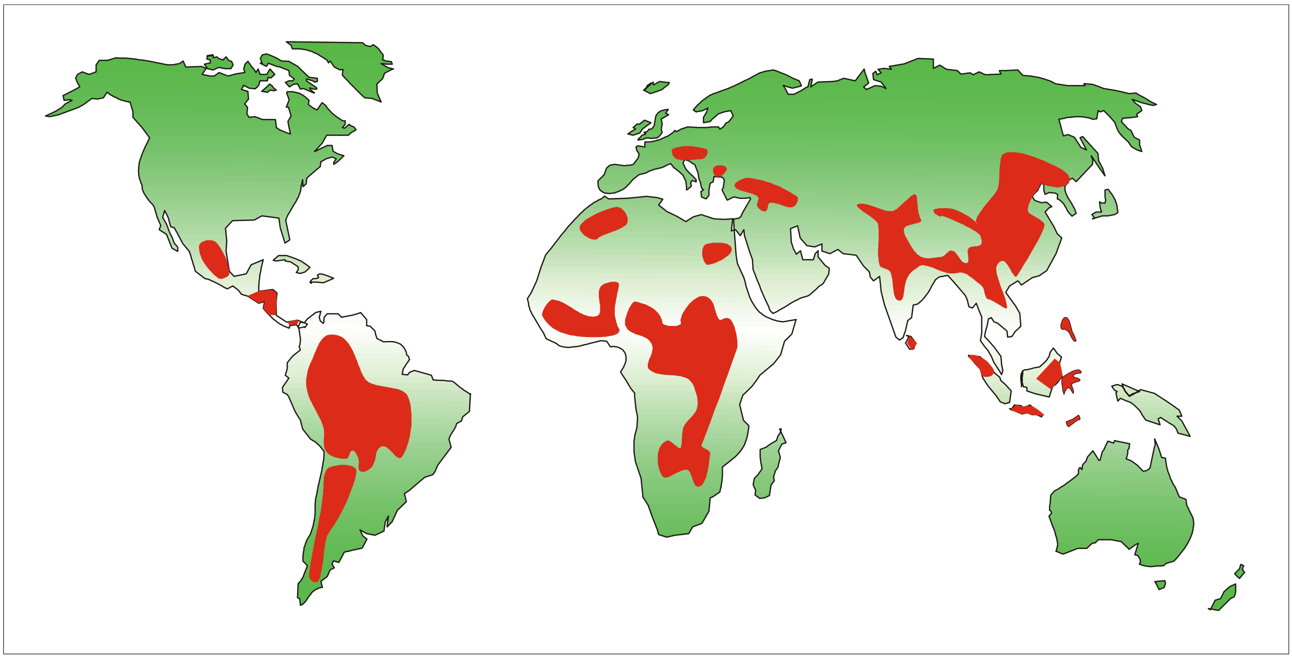

Figure 1. World distribution of recognised iodine deficiency. Other areas, especially in Africa and the Middle East, may also have iodine-deficiency problems, but have not been surveyed in detail (from Dunn and van der Haar, 1990).

Field testing for iodine

Field-test kits are available for iodine. However, they are generally designed for measurement of samples with higher concentrations (greater than around 0.5 mg/l) than those found typically in natural groundwaters (e.g. swimming pools). Iodine determinations are therefore best carried out in the laboratory, by colorimetric or ion-chromatographic methods. A suitable approach would be to instigate a randomised survey of selected groundwaters in areas with suspected problems or vulnerable aquifers to establish the typical ranges.

Remediation

It is important to recognise the vulnerability of communities in developing countries to IDDs by health surveys and determination of the iodine concentrations present in local drinking waters, soils and foods.

The best means of mitigation of IDD problems in endemic populations once recognised is the administration of dietary supplements. This then, rather than being strictly a groundwater-quality problem, becomes a social problem requiring local government intervention and significantly improved health-care education.

Dietary iodine supplements are an effective means of treatment of the goitre problem, provided that treatment begins early. Small goitres regress effectively after supplementary iodine is administered but treatment becomes less effective and more difficult at more advanced stages of the disease as the enlarged gland may become hard and nodular and underlying fibrous changes may have taken place (Phillips et al., 1988). Such nodular goitres require surgery. Recommended iodine supplements include use of iodised salt or the use of slow-release oral or intra-muscular iodine supplements (e.g. iodised oil). Administration of iodised salt can often prove difficult in developing countries due to difficulties of manufacture and distribution, particularly in remote areas. Iodised oil is often a more appropriate solution if administration by means of salt proves difficult as it ensures that the people most in need receive treatment and, once administered, can be effective for several years (Phillips et al., 1988).

Data sources

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