# Iodine status in UK–An accidental public health triumph gone sour

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# Iodine status in UK– an accidental public health triumph gone sour

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## Abstract

The improvement in iodine status among the UK population from the 1930s onwards has been described as an "accidental public health triumph" despite the lack of any iodine fortification program. However, iodine deficiency in the UK has re-emerged in vulnerable groups and is likely due to a combination of changing farming practices, dietary preferences and public health priorities. The UK is now among only a minority of European countries with no legislative framework for iodine fortification. The experience of folic acid fortification and the 28-year delay in its implementation lays bare the political difficulties of introducing any fortification program in the UK. If iodine fortification is not an imminent possibility, then it is important to explore other options: how to change farming practice especially on organic farms; encourage dairy intake; protect and expand our public health programs of milk provision for vulnerable groups and embark on education programs for women of childbearing potential and health care professionals. This review explores how the UK may have arrived at this juncture and how the iodine status of the nation may be improved at this time of major political and public health upheaval.

## Introduction

The Arab geographer Mas'udi described the inhabitants of 10$^{th}$ c Europe as having "large bodies… dull understanding and heavy tongues", indicative of cretinism due to severe iodine deficiency in utero. [1] Later Paracelsus, the Swiss physician of the 16th c, pointed out the relationship between goitrous parents and their mentally disabled children.[1] Milk, fish and, to a lesser extent, salt are the richest sources of iodine, but milk was regarded as a poor man's drink and avoided by the wealthy classes in the Middle Ages. [2] Salt was expensive but, over time, trade routes opened up to bring rock salt from India and the Sahara, and the Norwegian Vikings developed the process of drying and salting cod. Fishing grounds that would otherwise have been too far from population centres to provide fresh fish slowly became a rich source of iodine for Europeans. Some have conjectured that a slow improvement in iodine status may have contributed to the northern European peoples progressing into the Enlightened Era. [2]

Iodine deficiency was still prevalent in the British Isles up to the 20$^{th}$ century, with reports that "goitre was as common in the Yorkshire dales as in…any of the Alpine valleys" [3,4] A 1924 survey from England and Wales reported visible goitre in up to 30% of 12-year-old children. [5] Similarly, during the Second World War years, visible goitre was noted in 50% of adult women and 26-43% of schoolgirls in Oxfordshire and Dorset. [6] The Medical Research Council called for the introduction of an iodized salt programme in 1944 and 1948 but, while other countries with endemic iodine deficiency moved in this direction, the UK and Ireland held back. [6, 7]

The reasons for this are unclear but with the development of food analysis science at the end of the 19th C, parliamentary minds appear to have been more concentrated on preventing the addition of toxic substances to food than enabling fortification (eg in the 1912 and 1925 Acts of Parliament). [8] At the same time in the US, dietary reformers including John Harvey Kellogg and other "pure food" advocates were arguing that foods were being adulterated and rendered unsafe by "additives" and lobbied for appropriate legislation.[9] The UK parliament is reported to have had the most developed lobbying system in Western Europe and this may have been soft wired into the government decision making of the day. [10]

From the 1930s, iodine started to be added to cattle feeds, as it was thought to enhance animal fertility and promote lactation. Large scale milking parlours became more commonplace during the war and iodine-containing disinfectants were increasingly used to clean both the parlour equipment and the teats to reduce bacterial contamination from mastitis. The resulting increase in iodine in the food chain has been described as an "accidental public health triumph." [11]

During the era of rationing, the UK passed into law a series of milk acts for pregnant women and children, culminating in the Free School Milk Act of 1946 that provided free cow's milk (190ml, 1/3rd pint per day) to all children under the age of 18 at school. [12]

The combination of these husbandry changes and the public health policy around milk led, in spite of no action on fortification, to a drop off of endemic goitre, as evidenced in a 1990 survey of schoolchildren in a traditionally iodine-deficient area of South Wales. [13] The last UK national survey reporting iodine repletion was in 1992. [14]

Indeed, some reports of iodine excess were reported during this period. Individuals in whom the chronic iodine deficiency has induced thyroid hyperplasia and goitre with autonomous thyroid follicular cells may respond to excessive intake with resultant hyperthyroidism.[11] Hypothyroidism has also been reported to have increased in Denmark since mandatory iodisation of salt was introduced in 1998 notably in subjects aged 20-59 years with previous moderate iodine deficiency.[15] However the Scientific Advisory Committee for Nutrition (SACN), has on balance taken the position in its 2014 paper that "at a population level in the UK there are no concerns about excessive dietary iodine intakes".[16]

**British Isles iodine status in the 21st c**

The World Health Organisation (WHO) defines iodine deficiency as a population survey median urinary iodine concentration (mUIC) <100 μg/L outside of pregnancy (along with <20% of population <50 μg/L) and <150 μg/L during pregnancy. Adequacy is regarded as a mUIC of 100-200 μg/L outside of pregnancy and 150-250 μg/L during pregnancy. [17] Iodine sufficiency was assumed until, in 2011, a large UK survey of 700 teenage girls reported a mUIC of 80 μg/L in the deficient range. [18] The SACN in their 2014 position paper noted that teenage girls, milk and fish avoiders and vegans may be at particular risk of iodine deficiency.[16] In 2015 an all-Ireland survey of 900 teenage girls demonstrated a levels in the low sufficiency range mUIC of 111 μg/L. [19] The most recent UK National Diet and Nutrition Survey (NDNS) based on 2016-2018 data found that the mUIC for women aged 16–49 years (n=426) was borderline normal at 102 μg/L with 17% of that population <50 μg/L. [20] The UK Iodine Group called for caution in interpretation of the NDNS results pointing out that pregnant women were excluded and that the age range was very wide so that the presented results may mask deficiency in some vulnerable groups. [21] Taken together these studies in non-pregnant women and teenage girls might be described as fitting a pattern of "bumping along the bottom" of sufficiency and into mild deficiency.

The pregnant population over this time has, if anything, fared worse. Surveys of iodine status completed in Wales, Northern Ireland, the Republic of Ireland and four areas of England are listed in Table 1. [22-29] A further study in Scotland relied on food frequency questionnaires

(FFQ) to assess iodine intake rather than population urinary iodine sampling.[30] The studies are consistent in reporting population iodine deficiency (42-135 µg/L), with no suggestion of improvement over the 25-year period in which these surveys were carried out.

**Significance of mild iodine deficiency during pregnancy**

Iodine requirements during pregnancy increase for many reasons: an increase in the maternal thyroid hormone production, placental transfer of iodine for fetal thyroid hormone production, increased urinary losses associated with the increased glomerular filtration of later pregnancy and lastly sequestration to the breast.[3] The WHO recommends an increased iodine intake from 150 to 250 µg per day for mothers and those planning pregnancies to meet these increasing demands.[17] It also recommends spot median urinary iodine concentration (mUIC) targets for pregnant population surveys of >150–249 µg/L as opposed to >100 µg/L outside of pregnancy and nursing. The American Thyroid Association (ATA) recognises the geographical differences in iodine availability in food chains and recommends that different regions develop strategies for ensuring adequate iodine intake during preconception, pregnancy and lactation.[31]

The effect of moderate to severe iodine deficiency during pregnancy has long been recognised as cretinism in the offspring.[3,17] In regions with moderate and severe population iodine deficiency, randomised controlled trials of iodine supplements in pregnancy have demonstrated improved neurological development of offspring.[3,17]

The effects of mild iodine deficiency in pregnancy and its correction have been less clear. However, the UK " Avon Longitudinal Study of Parents and Children" (ALSPAC) recently reported that lower iodine status in the first trimester was associated with offspring reading ability, Key Stage 2 academic scores and intelligence quotient (IQ) (at ages 8- 11) in a dose-dependent pattern.[29] A 15-year follow-up of offspring with mild iodine gestational deficiency in Australia has shown persistent auditory processing speed and working memory differences. [32] Further, a meta-analysis of 6000 mother-child pairs from the Netherlands, Spain and the United Kingdom from 1990-2008 reported an association between maternal iodine status and offspring verbal IQ, with the association confined to first trimester iodine status only. [33] The “Born in Bradford” cohort of 7000 mothers from 2007-2010 were surveyed in the second trimester (mUIc 76 μg/L).[34] Lower maternal iodine status was associated with lower birthweight and whilst the effect size was small, it was comparable to tobacco smoke exposure. The authors concluded that strategies to avoid deficiency in women of reproductive age should be considered.

Studies of the efficacy of iodine supplementation during pregnancy in this group with milder deficiency have been mixed in terms of neuropsychological improvement. [35-37] These studies are felt by many to be nearly impossible to design, because recruitment should be at pregnancy onset, given that fetal brain development is promoted by maternal thyroid hormone from week four of pregnancy. Authors are increasingly calling for population sufficiency programmes with childhood outcome studies attached as opposed to interventions during pregnancy studies, not least because pregnancy is only planned in approximately 40-50% of cases. [38,39]

**Reasons for change in iodine status**

The reasons for the recent deterioration in iodine status in the UK is likely threefold: changing farming practices, changing dietary preferences and changing public health priorities around milk provision, with no buffer of an iodine fortification programme. Fortification via salt iodization is the main strategy endorsed by the WHO and has been undertaken by many countries to ensure adequate population intake of iodine. [17] The USA has a successful voluntary iodised salt program for breadmaking while Australia and New

Zealand have mandatory iodised salt fortification programs for bread.[40] In contrast, the UK is one of only 12 countries within the block of 40 European countries, which has no legislation for mandatory or voluntary iodine fortification. The impact of fortification programs has been deemed to be very positive, although some studies, in, for example Australia, and the Nordic countries, have suggested that fortification is necessary but may not be sufficient to achieve optimal iodine nutrition, especially with the reduced salt intake in populations over time. [41,42] The experience of folic acid fortification and the 28-year delay in its implementation lays bare the political difficulties of any fortification programme for the UK.[43] If iodine fortification is not an imminent possibility, it is then important to urgently explore and exhaust the avenues of changing farming practice, dietary choices and other potential public health strategies.

**Changes in farming practices**:

Farming practices have changed considerably over the last half century, with milk yield per dairy cow increasing by ~50%.[44] The iodine content of conventionally produced cow's milk doubled over the decade 1985 to 1995 and remained static over the following decade at ~ median 300 µg/L. [16] This compares favourably with other countries e.g. Denmark ~120 µg/L, Australia ~195 µg/L and Spain~260 µg/L.[45-47] This may be due, in part, to the continued use of iodophor disinfectant in milking parlours, while these have been replaced in some other countries e.g. Australia and New Zealand. [45]

The flow of iodine through agro-ecosystems including milk, soil, silage, grass, and different animal feeds is not well understood. [48]A recent UK report suggested that natural iodine inputs into the environment are dominated by atmospheric deposition, especially sea spray, and so the location of farms relative to the coast and prevailing wind direction is important.[49] The levels of iodine in supplemental feeds were approximately 10-fold higher than those in forage-derived feeds and the practice of feed supplementation led to elevated milk iodine. [49]

The iodine content of animal feed is controlled by the legislature. In 2005 the maximum permitted levels for iodine in feeds were reduced from 10 mg/kg to 5mg/kg for dairy cows and laying hens, because of a concern that levels may exceed the "tolerable upper limit "- in the food-chain causing human toxicity. [16] The recent population surveys consistently show no evidence of a tolerable upper limit, but rather borderline iodine deficiency. [16]

Organic milk is increasingly popular, but is lower in iodine content than conventional milk by ~25-40% and iodine status (measured by mUIC) is lower in those consuming organic milk than conventional milk .[50,51] Animals reared on organic farms are required, by law, to be fed outside on pasture for at least 200 days per year and additional feeds must be at least 60% own-farm generated. [52] The common practice of using clover pasturage on organic farms (an alternative to nitrogen fertiliser) reduces further the amount of iodine circulating into milk. [50] Mineral supplementation is only permitted on organic farms in very restricted circumstances. The onus is on the farm to demonstrate that it is unable to meet mineral requirements and is subject to state body permissions, the bureaucracy of which is likely to be prohibitive to achieving good iodine levels. [52]

**Changes in dietary preferences and the "post-milk" era**

Cow's milk intake has been in decline over the last 50 years and intake amongst females women, children and teenagers is especially low. [18,19,28,53] A consistent dose-dependent relationship has been demonstrated between iodine status and milk and dairy intake among teenage girls in the UK.[18,19] The WHO recommends an intake of 250 µg iodine in pregnancy and one pint of cow's milk (560ml) equates to approximately 140-224µg of iodine. [17]

Alternative milks such as soya, almond, rice, coconut and oat are increasingly visible in supermarkets and UK coffee chains. A recent UK study demonstrated that median iodine concentration of milk-alternative drinks was very low, at ~7µg/L, <2% of the value for winter conventional cows' milk (see Figure 2). [53] Fortification with iodine only occurred in 6% of the milks identified.

In population surveys, those who reported consuming milk alternatives were found to have the lowest mUICs compared to those who consumed cow milk. [53] The number of vegans in Britain has reportedly quadrupled from 2014 to 2018 to 600,000.[54] Although this is still only ~1% of the population, vegan compatible milks have increased in popularity to 2% market share by volume and global sales set to increase from 17 to 30 billion US Dollars from 2018 to 2023.[55] Concern remains about whether companies should be able to call a product "milk" that is not derived from lactating animals, causing confusion for the consumer. One French study of hospital admissions of infants between 2008 and 2011 reported complications from plant-based milk diets which included protein-calorie malnutrition, refractory status epilepticus (hyponatraemia), failure to thrive, rickets, iron deficiency anaemia and scurvy.[56]

Environmental concerns are one of the reasons behind these behavioural shifts and are used as one of the main marketing strategies of alternative milk companies. Farming research has recently focused on reducing greenhouse gas production from milking cows. Programmes include cow vaccination studies against methane producing microbes, genetic and breeding programmes using sexed semen, probiotic and precision nutrition studies. [57,58] The UK National Farmers Union has set a target for farming to become net carbon zero by 2040 – 10 years ahead of the government's target in an effort to improve the messaging about cow's milk and the environment. National television campaigns by the Milk Marketing Board finished with its dissolution in 2002 and while Dairy Councils took on the mantle, the approach was lower key. Slogans included "full of natural goodness", "milk's gotta lotta bottle" and "drinka pinta milka day" have been replaced by the alternative milk industry call to join the “Post Milk Generation” and slogans of “Wow! No cow”.

## Changes and Omissions in Public Health Policies

### (i) Provision of free and subsidised cow’s milk

Free milk provision in primary and secondary schools lasted for more than 20 years but was gradually withdrawn from 1968 to 1977. [12,18] We know that milk intake in schools has drastically reduced since the withdrawal of universal free school milk. The current European Union (EU) school milk subsidy scheme aims to reduce the cost of milk and yoghurt for primary and secondary school children. Currently milk cost re-imbursement is full only for those under 5 years, and additionally in Wales for key stage one (up to age 7 years). Partial re-imbursement is available for the rest of primary and secondary school pupils but is not available for pupils in further education facilities. Overall, this falls well short of free provision and uptake by schools is low. For example, in 2018/19, 1.5 million out of 9.4 million children eligible in the UK were recipients of subsidised milk costing approximately €4m matched by £3.4m from national government funds .[59] Post Brexit (UK withdrawal from the EU), the future of EU schemes linked to agriculture will be in doubt up for re-discussion. Indeed, a consultation on the school milk scheme took place in 2017 after the June 2016 Brexit vote, with only a short-term commitment made to end of 2020.

The Healthy Start Programme commenced in the UK in 2006 for pregnant women and women with young children either on low income or who are <18 years. The scheme provides vitamins and vouchers (~£3 per week) for milk, fruit and vegetables. Results have been mixed and some women have, perhaps not surprisingly given their vulnerability and conflicting priorities, used this resource to reduce food expenditure rather than improve their diet. A recent study has shown that for some women who struggled to manage financially, the Healthy Start vouchers were used to deduct money from the shopping bill and the money saved was redirected towards other things that were considered more important.[60]

**(ii) Supplementation of iodine in pregnancy:** The Scientific Advisory Committee for Nutrition (SACN) in the UK does not specifically recommend supplementation (or indeed increased intake) during pregnancy, instead calling for further research. [16] This position is at variance with other nations such as Australia and USA who recommend a supplement containing 150 µg iodine daily. [31,43] A meta-analysis has recently suggested that iodine supplementation in pregnancy is likely to be cost-effective, with savings of £199 in healthcare costs and £4476 societal costs. [61] However, a recent Cochrane database study found insufficient robust data to reach any meaningful conclusions on the benefits of routine iodine supplementation in women before, during or after pregnancy. [62] It may never, in reality, be possible is difficult to achieve good quality studies in this area, given the two inter-related challenges of recruitment, ideally within the first four weeks of pregnancy, and the knock-on bias of an over-representation of planned pregnancies. The most commonly used pregnancy multiple nutrient supplements taken in 1st trimester contain ~140-150 µg iodine /tablet. Pregnant women who live in an iodine deplete area and who take iodine supplements have improved iodine status but may remain below the recommended level. A recent Northern Irish pregnant cohort was demonstrated to have iodine deficiency throughout all trimesters, despite 53% of women taking a pregnancy-related supplement containing iodine.[28] Supplementation in an iodine deplete area may therefore not be sufficient without also an iodine fortification or education program.

**(iii) Public health education**

Public health bodies in the UK have not highlighted iodine nutrition in pregnancy historically. For example, the NI ‘Pregnancy Book’ contains information about folic acid, vitamin D, iron, vitamin C and calcium, but not iodine.[63] Similarly the NHS website does not mention iodine nutrition in pregnancy. Only 5% of 200 recently surveyed pregnant women in UK felt they had been given enough advice about iodine.[64] Motivation among women to make appropriate dietary changes in pregnancy is high, with 87% in one study reporting willingness to alter their diet during pregnancy if provided with adequate information.[65] However, dietary education has not been shown to consistently translate to improved iodine status and is unlikely to be effective on its own as a strategy. [66, 67] Community midwives appear to be the main source of dietary advice in pregnancy in the UK, but their first interaction with otherwise healthy pregnant women is usually at the end of first trimester, when the window for iodine optimisation has passed. A recent Australian survey of 329 midwives reported that 93% provided nutrition advice, but only ~50% reported receiving nutrition education during their careers and, when asked about iodine requirements, 80% gave incorrect responses. [68]

**Conclusion:** An urgent need exists to protect unborn children in the UK. With no protection afforded from an iodine-fortification programme and iodine status in the deficient range, our pregnant population are now vulnerable. The UK journey to folic acid fortification, which has still not been achieved, points to the political difficulties of any fortification programme for the UK. Iodine fortification is a cornerstone requirement for optimal nutritional status of the population but, in its absence, changes to husbandry, dietary habits and education strategies are urgently required.

Farming standards should be part of any review and consideration should be given to re-instating the higher maximum iodine level in livestock feed for geographical areas with poor soil levels of iodine. A relaxation of organic farm rules around mineralization supplements should also be considered. These technical changes, along with active government encouragements and incentives to enact these changes, may be a more politically palatable strategy to increase iodine in the nation's food chain.

Efforts should be made to change dietary habits to improve iodine status in the general population, especially in children and women of childbearing years, given the high rate of unplanned pregnancies. It has been suggested that habit-forming strategies should centre on making choices "Obvious, Attractive, Easy and Satisfying" which correspond to the psychological pillars of "Cue, Craving, Response and Reward". [69] An expanded school milk provision to universal schemes should be considered to promote good dietary habits and is achievable in any first world country. This would satisfy the "attractive and easy" requirements for behavioural change. The "satisfying" requirement is much helped in the modern-day era of fridges in schools, which were a luxury for many schools in the 1940s-70s. Children are acutely aware of difference and the provision of free milk only to those on low income risks the return of the construct of cow's milk as the "poor people's drink".

Consideration should also be given to expanded public health schemes to provide milk and iodine containing supplements to women contemplating pregnancy, pregnant and nursing women. One recent randomised controlled study of free milk provision in non-pregnant women demonstrated a doubling of intake from <140mls/day and an improvement in mUIC from a deficient range to a sufficient range after three months.[70]

Public health awareness campaigns around the benefits of cows' milk iodine could satisfy the "obvious and attractive" requirements for positive dietary change. These should include explanations of the limitations of alternative milks and their unsuitability in pregnancy. At present women are poorly equipped to make positive dietary changes to meet the increased iodine requirements in the peri-pregnancy period. Promotion of the British Dietetics Association iodine food fact sheet may be a good first step.[71] The legislature should consider restricting the use of the term "milk" by alternative drinks companies.

The SACN has called for further research in order to make national recommendations. However, it is increasingly clear that research should focus less on demonstrating the importance of iodine optimisation during pregnancy. Rather research should focus on the most impactful strategies to achieve iodine optimisation in the population with robust outcome measures in the offspring of the nation. Given the national nature of our health service and the strength of our public health research capabilities, the UK is very well placed to answer these questions.

**Summary Box: Proposed recommendations to optimise iodine status in the population in the absence of iodine fortification measures**

1. **Farming practices**
    a. Relax mineral supplement rules for organic farms
    b. Consider re-instating the higher maximum iodine level in livestock feed for geographical areas with poor soil levels of iodine
    c. Provide government incentives for farmers to enact change
2. **Dietary Habits**
    a. Habit forming strategies- expand school milk provision to restore universal schemes
    b. Expand schemes that provide milk and iodine supplements to women planning pregnancy, pregnant and nursing women
    c. Promote the British Dietetic Association iodine fact sheet
3. **Public Health Initiatives**
    a. Actively highlight to women the unsuitability of alternative milks in pregnancy
    b. Consider legislation to restrict the use of the term "milk" by alternative drinks companies
4. **Research**
    a. Fund nationwide studies that seek to optimise iodine status in the population with robust outcome measures
    b. Explore how to best educate our health care professionals and women of childbearing potential about optimising iodine nutrition during pregnancy and breastfeeding

**Table 1**

**First trimester iodine status from cohorts in eight regions of the British Isles 1991-2015**

| | Year | No. | mUIC (sufficiency>150 µg/L) |
|---|---|---|---|
| SW England [29] | 1991 | 1040 | 91 |
| Rep of Ireland [22] | 1997 | 79 | 135 |
| NE England [23] | 2000 | 227 | 40% "borderline" |
| Wales [24] | 2002-6 | 383 | 117 |
| Rep of Ireland [25] | 2004 | 54 | 68 |
| SE England [26] | 2009 | 100 | 85 |
| S England [27] | 2009-11 | 230 | 42 |
| N Ireland[28] | 2014 | 217 | 73 |

mUIC- median urinary iodine concentration; (Adapted from Clin Endo 2019)

**Figure 1 Endemic regions of goitre: England and Wales 1960**

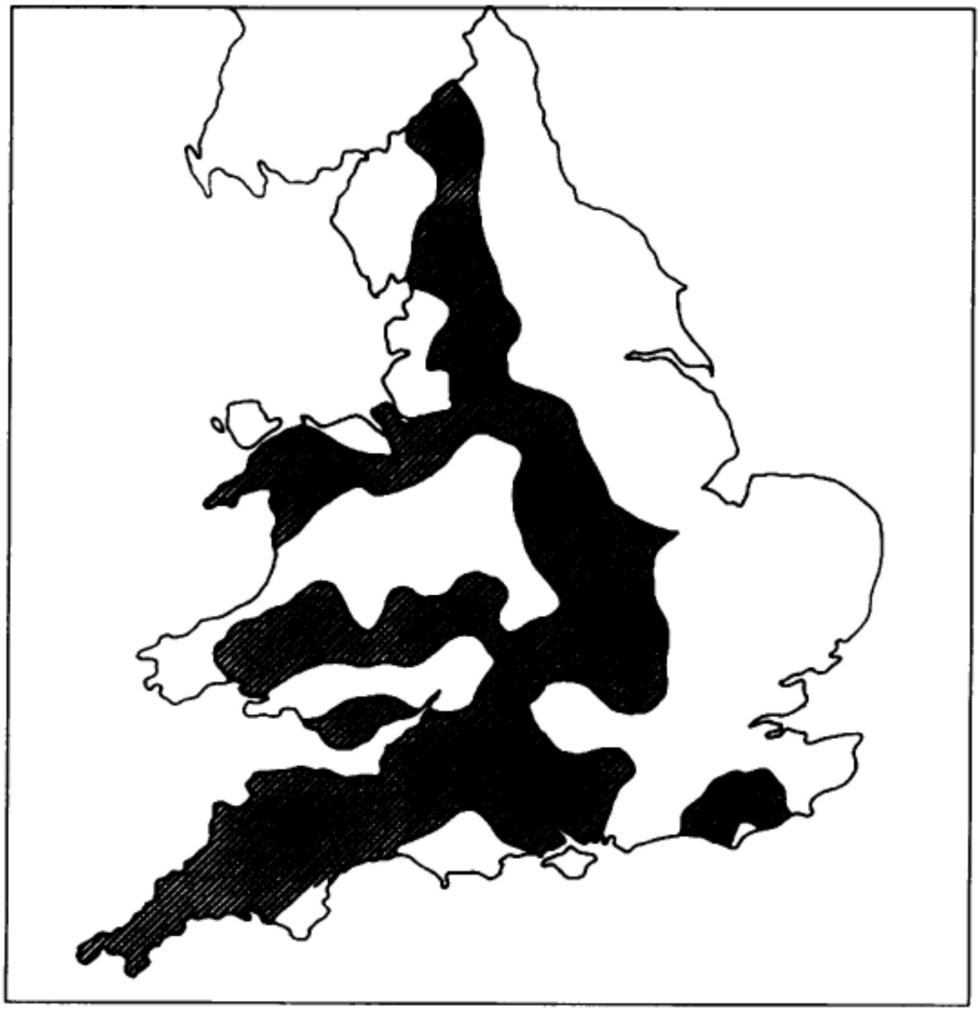

*Figure 1 Areas of England and Wales where endemic goitre has been prevalent in the past.*[24].

Kelly FC et al; Endemic goitre.WHO.Monograph Series No 44. Geneva:WHO,1960:105-9; permission pending

**Figure 2 Iodine concentration of milk-alternative drinks in UK**

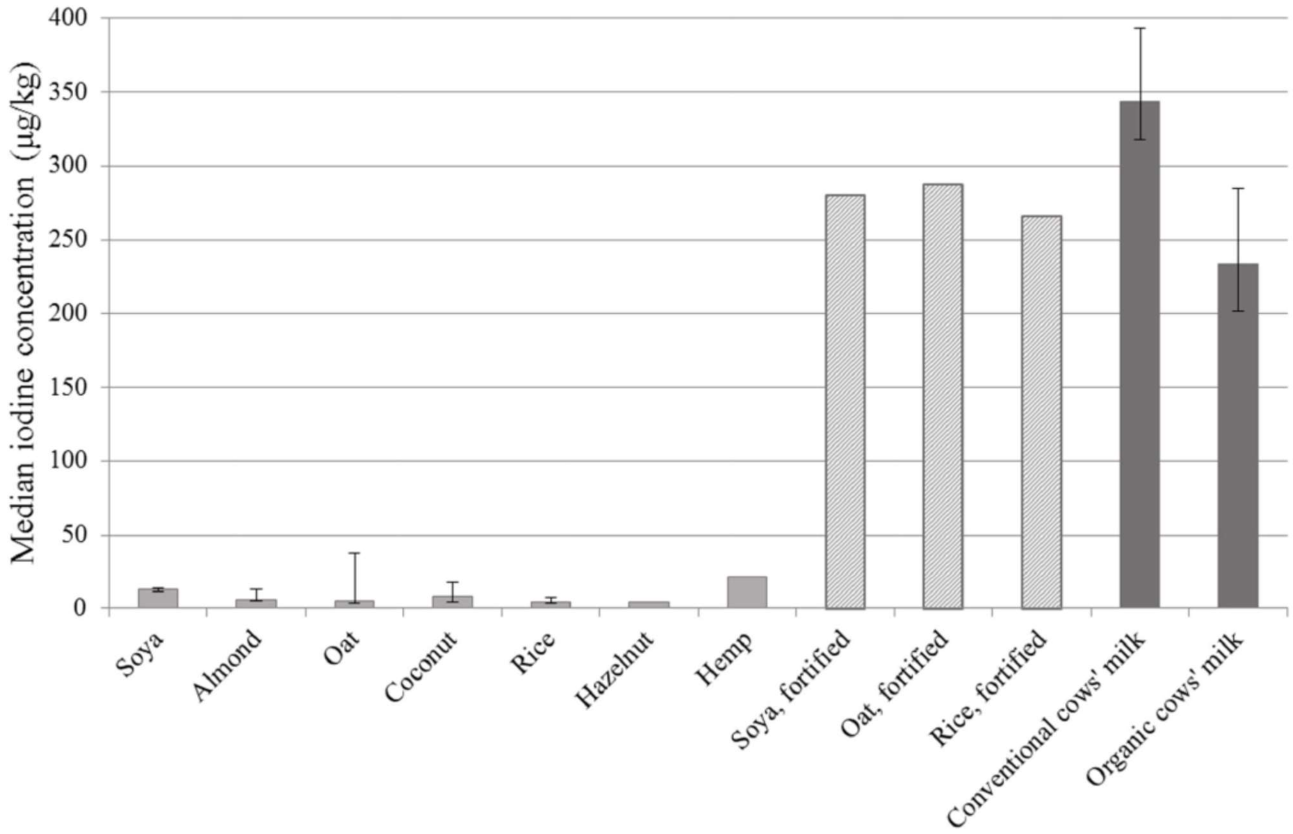


Figure from Bath 2017- permission to be confirmed

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