British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

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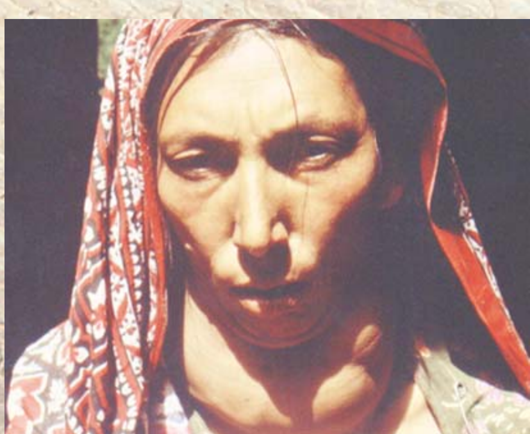
Environmental Controls In Iodine Deficiency Disorders



SUMMARY:

An understanding of the role of iodine in endemic goitre was the first recognised association between a trace element in the environment and human health. Iodine deficiency disorders (IDD), which include goitre (a swelling of the thyroid gland in the neck), are a group of diseases that result from a relative lack of iodine in the diet. It is the single most common cause of preventable mental retardation and 38% of the world's population are said to be at risk from IDD. Medical intervention techniques, for example iodisation of table salt, are well-established and have been responsible for reducing the global problem.

This report summarises our study of environmental factors implicated in producing iodine-deficient environments and how an improved understanding of iodine geochemistry can be used to reduce the IDD risks. Two case studies from Xinjiang Province, China and the Atlas Mountains, Morocco are discussed and the geochemical behaviour of iodine in the environment summarised.

With a better knowledge of the geochemical behaviour of iodine and its migration through the food chain we can suggest environmental solutions for reducing the risks of IDD. The natural content can be better managed to achieve a more favourable supply of bioavailable iodine. The retention of this mobile trace element in the soil has to be encouraged but it must not become so strongly fixed that it is no longer bioavailable. The soil Eh/pH, organic content, and soil texture are seen to be important controlling factors.

In areas of significant iodine-deficiency, where the local population have little or no scope for managing their own environment because of extreme poverty and harsh conditions, adding iodine from an outside source is the only practical approach. This can be achieved by adding iodine to water used for drinking and irrigation or using iodine-rich fertilisers. However, such supplementation can only be cost effective if measures are taken to ensure that the iodine is not readily lost from the environment to which it has been added.

In most areas of the world, with the exception of generally iodine-rich coastal regions, populations totally dependent on the local environment for their source of iodine are likely to have iodine deficient diets. Undeveloped regions lack the access the more iodine-rich food sources (e.g. seafood) and the adventitious sources of iodine added during food processing.

Moderate goitre, China.

Children waiting to be weighed, China.

Sacks of wheat, a staple crop in China.

Environmental Controls in Iodine Deficiency Disorders
Project Summary Report

Commissioned Report CR/03/058N
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All photographs in this report were taken by project team members Alex Stewart, Fiona Fordyce and Mick Strutt.

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INTRODUCTION:

The importance of Iodine

We all face a danger if our diet lacks iodine and the consequence is a number of medical conditions grouped under the general heading of iodine deficiency disorders (IDD). Only a trace amount of iodine is required, as little as 100–150 μg is the recommended daily dose, less than three grammes of iodine during the course of a lifetime. Cretinism, mental retardation, decreased fertility, increased perinatal death and infant mortality will result from instances of severe iodine deficiency.

An understanding of the role of iodine in endemic goitre was the first recognised association between a trace element in the environment and human health. Treatment of goitre using iodine rich seaweed has been used for thousands of years though it was not until the early 1900's that the need for iodine in the diet (specifically for its thyroid function) was recognised.

The main thrust of effort to reduce the risks from iodine deficiency disorders is coordinated by the International Council for the Control of Iodine Deficiency Disorders (ICCIDD). This is *'a non-profit, non-government organization for the sustainable elimination of iodine deficiency and the promotion of optimal iodine nutrition worldwide'*. Much of the effort in eliminating IDD centres on the use of medical prophylaxes and proceeds relatively successfully without a sound understanding of its principal cause, a deficiency of iodine in the environment. There is a perceived need for a better understanding of the geochemistry of iodine so we can ensure that the small environmental amounts available are used in the most efficient way. Hence, where iodine is added directly to the environment by methods such as dripping into irrigation water we will be better able to ensure that it reaches the food chain.

The aim of this project has been to look at factors controlling the bioavailability of iodine in the Earth's surface and suggest environmental solutions to reduce the risks from IDD by supplementing medical intervention schemes where necessary. The output from the work is specifically aimed at informing the medical community about the geochemical behaviour of iodine in the environment.

The project uses data gathered from two case studies in China and Morocco and a comprehensive bibliography covering iodine geochemistry. Information from these sources has been interpreted to give us a clearer understanding of the behaviour of iodine in the surface environment. Strategies for more efficient use of environmental iodine are proposed, along with a summary of environmental intervention schemes that have been employed by other researchers.

Photo opposite: *Collecting soil and crop samples, China.*

IDD Problem Statement from the ICCIDD

'Iodine deficiency is the single most common cause of preventable mental retardation and brain damage in the world. It also decreases child survival, causes goitres, and impairs growth and development. Iodine deficiency in pregnant women causes miscarriages, stillbirths, and other complications. Children with IDD can grow up stunted, apathetic, mentally retarded, and incapable of normal movements, speech, or hearing. Globally, 2.2 billion people (38% of the world's population) live in areas with iodine deficiency and risk its complications.

Iodine deficiency was once considered a minor problem, causing goitre, an unsightly but seemingly benign cosmetic blemish. However, it is now known that the effects on the developing brain are much more deadly, and constitute a threat to the social and economic development of many countries.'


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OVERVIEW:

Iodine Deficiency Disorders

The iodine deficiency disorders are a group of diseases that result from a relative lack of iodine in the diet. They are found throughout the world, in countries at all stages of development, although they are commoner in remote and deprived communities. The disorders include goitre (a swelling of the thyroid gland in the neck), cretinism (mental retardation with physical deformities), reduced IQ, miscarriages, birth defects and deaths around the time of birth.

Cretinism is the commonest avoidable cause of mental retardation on a global scale. It can be prevented by a sufficient supply of iodine to a pregnant woman, but once present is irreversible. Supplying iodine to pregnant women also reduces the other disorders associated with pregnancy.

Goitre is unsightly, but usually does no harm. It is the easiest of the disorders to measure and is used as a marker of the presence of iodine deficiency in a community. However, the presence of goitre must not be taken to indicate a lack of iodine in the local environment or food chain.

The links between the environmental supply of iodine and the dietary intake remain unclear at this point and are sometimes compromised by the presence of other, competing factors which can accentuate the results of iodine deficiency in the body.

Much worldwide effort has gone into supplying iodised salt to communities at risk of the disorders. Iodised salt remains an easy means of supplementing the diet. However, too much iodine in a deficient community can lead to problems of toxicity and the results of any distribution of iodised salt needs careful monitoring. Other methods of control should be developed to complement iodised salt use.

Photo opposite: *A resident of the Ounein Valley (Morocco) with a large goitre.*

Mothers and children are most at risk of IDD.

Ultrasound scanning of the thyroid, China.

Food, the main source of our iodine.

Iodine in the environment

Iodine is present at the Earth's surface in very small amounts and is what geochemists refer to as a trace element. A feature of iodine geochemistry that distinguishes it from other trace elements is its mobility in the surface environment. This characteristic makes it a critical component of radioactive waste management, because radioactive iodine is a by-product of the nuclear industry and there is concern over environmental contamination. Much of our recent knowledge of iodine's geochemical behaviour comes from migration studies of iodine radioisotopes.

Seawater is a major source of iodine in the geochemical cycle with average concentrations of around 58 µg/l iodine *(figure opposite).* Iodate (IO_3^-) is the most stable form of iodine in seawater and this is reduced to iodide (I^-) in surface waters mediated by biological activity. Seaweeds and phytoplankton release iodine-containing organic gases (e.g. CH_3I and CH_2I_2) that pass into the atmosphere and are subjected to further chemical changes by the action of sunlight. Iodine in the atmosphere migrates inland and is deposited in wet or dry precipitation as a result of the prevailing climatological and topographical conditions.

As a result, coastal zones inevitably tend to be the most iodine-enriched environments. Studies of iodine in soils, crops and surface waters have shown a general decline in iodine levels away from the seacoast, although this is not a simple linear correlation. In surface soils located 0–50 km from the sea, for example, high but variable levels of iodine are found *(figure on page 8).* This is in contrast to inland soils where uniformly low levels of iodine predominate. Iodine can be re-volatilised from the soil-plant interface, also probably involving biological conversion of iodine to organic forms. It will migrate further away from the coast until precipitated again on the land.

The weathering of rocks is also a source of iodine in the surface environment. Organic-rich shales, for example, can average as much as 20 µg/g I. However, such rocks in terms of overall global distribution are rare and the Earth's continental crust is dominated by rocks averaging only 0.2 µg/g I and contributing relatively little iodine to surface soils. In terms of iodine deficiency disorders, it is the pathways from soil-plant-man and water-man that are of the most importance and iodine in soil, drinking waters and crops will be described in more detail here.

Iodine in soil

The iodine status of a soil is a combination of the supply of iodine and the soil's ability to retain it. A soil from a coastal zone may have a high input of iodine but if it cannot hold on to the iodine then it will remain deficient. The iodine fixation potential of a soil is a complex mixture of many factors that include the soil's organic content, the soil texture, the chemical form of the iodine, and the prevailing oxidation and acidity conditions (Eh/pH).


Sampling tap water, Morocco.

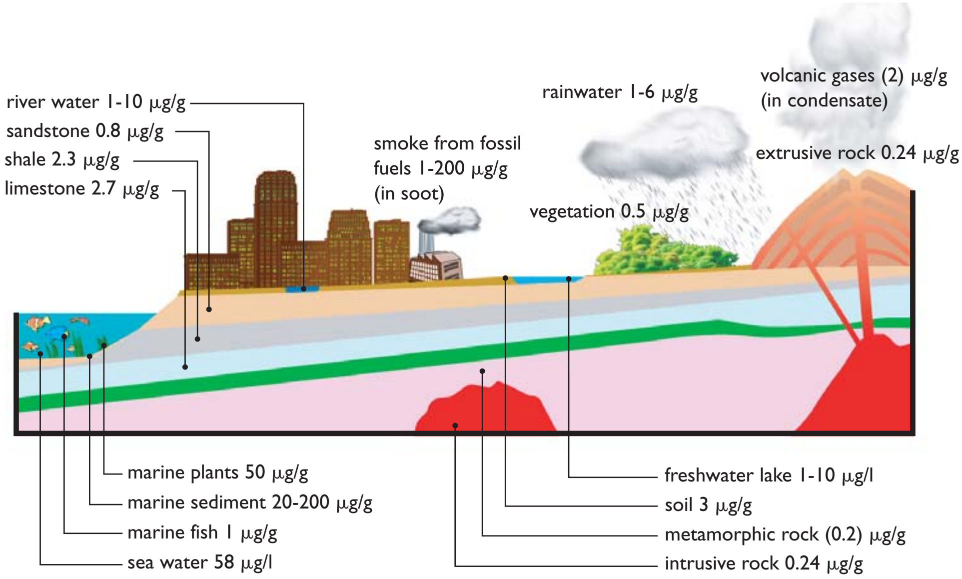

Subsistence agriculture, china.


Collecting a filtered water sample.

Salt formed in dry river valleys, Kuqa, China.

Sampling the grain store, Xinjiang, China.

Water alkalinity determination in the field.



The average iodine content for soils from the project's database (2151 results of screened data from all over the world) is 5.1 µg/g. However, given the skewed nature of the data distribution, the geometric mean of 3.0 µg/g is a more suitable value to quote for the level of iodine in soils. Research into iodine residence time in soils suggests that they equilibriate with the environment's levels relatively rapidly and it is unlikely that glacial soils from recent ice ages (c 10 000 years ago) are 'under saturated' with iodine.

Organic matter plays an important role in fixing iodine in the soil and peats tend to be the most iodine-enriched of all soils. On a textural classification for soils, the following order can be determined (mean value in µg/g I in brackets):

peat (7.0) > clay (4.3) > silt (3.0) > sand (2.2)

Contrary to what might be expected, organic-rich soils, whilst high in iodine, are not good providers of the element to the food chain because it is strongly fixed and not bioavailable. Any consideration relating the status of an environment to the iodine status of the population needs to look at the soil's bioavailable and not total iodine. Generally less than 10% of the soil's iodine can be extracted with cold water and this is a good indication of how much is bioavailable.

Iodide is the most mobile form of iodine in the soil and is more readily taken up by plants than iodate. Acidic soil conditions favour iodide whilst alkaline oxidising conditions (such as that found in dry thin soils of limestone areas) favour the less soluble iodate form. There is no need to invoke the presence of goitrogens in limestone areas that are noted for their high prevalence of IDD. Simple Eh/pH considerations would suggest the iodine in alkaline environments is less mobile.

Iodine in the environment

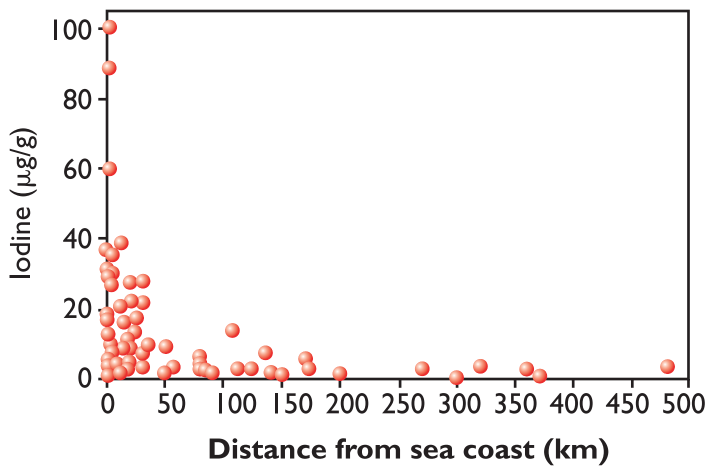
Iodine in drinking water

Surface waters are probably the best index of an environment's iodine status, although iodine deficiency disorders do occur in areas where water iodine levels are relatively high. Iodine in water represents the mobile form of the element (hence bioavailable) and waters are more easily analysed than soils and vegetation. Early work in the USA and UK suggests a threshold level of 3 µg/l below which an environment could be defined as iodine deficient. There is a wide range of results reported for the iodine content of drinking water from <0.1 to 150 µg/l, an average for all results being 4.4 µg/l. Those studies that have looked at drinking waters from a number of sources suggest artesian or deep water well supplies are most enriched in iodine. The general level of iodine reported in natural surface waters (rivers and lakes) ranges from 1–10 µg/l.

Drinking water generally provides about ten percent of the Recommended Dietary Allowance (RDA) which is 150 µg per day for iodine *(figure A opposite).* However, in regions dependent on the local environment for food, and without adventitious or iodine supplementation, drinking water can provide more than twenty percent of the daily iodine intake.

Iodine in foodstuffs

There is no evidence to suggest that iodine fulfils any role in terrestrial plants and there is no apparent correlation between the amount of total iodine in the soil and the content of crops. However, excessive iodine in the soil can be toxic to plants and this is illustrated by the occurrence in rice of 'Reclamation Akagare' disease, a physiological disorder caused by flooding paddy fields on iodine-rich soils.

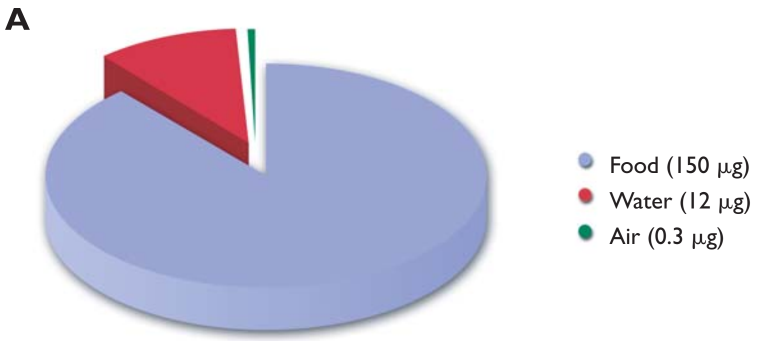


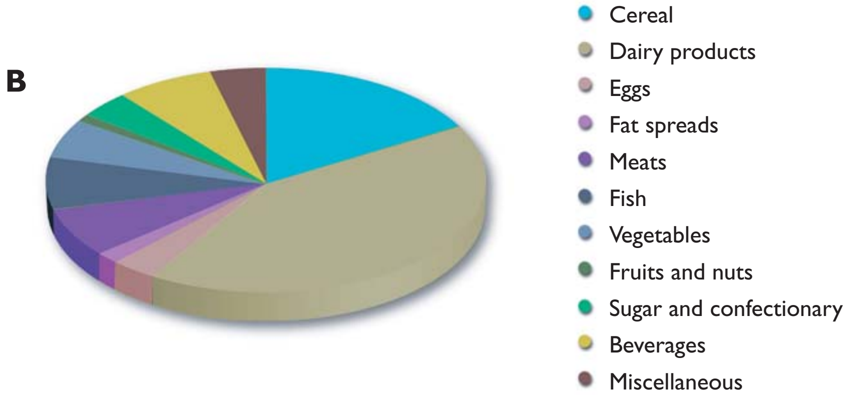
A plot of the total iodine content of surface soils plotted against distance from the sea coast.

Sandy soils of the Taklimakan Desert, China

Water sampling from the River Tuogishan, China.

Collecting a surface soil, near Agadir, Morocco.





(A) *Diagram showing the estimated relative proportions of food, water and air to the daily iodine intake of a person living in a developed country.*

(B) *Chart showing the relative contribution of iodine to the diet from different foods. Based on data from the UK National Diet and Nutrition Survey 1997–1998.*

Arable crops generally contain less than 50 µg/kg (fresh weight) iodine in the order legumes > vegetables > fruit. If a major pathway for iodine into the plant system is through leaf adsorption, then leafy vegetables must be considered to have an advantage in concentrating iodine. The iodine content of plants is seen to increase with the proportion of leaves. Iodine is not mobile in plants and is not concentrated in the seed. Processing the seed for food consumption is likely to decrease the iodine content further. Therefore, grain crops such as rice and wheat cannot therefore be considered as good providers of the element.

Grazing animals and their products are richer sources of iodine, they act as concentrators of the element by grazing large areas of pasture on which iodine has been precipitated from the atmosphere. The levels of iodine in milk, eggs and meat are further raised by adventitious sources added during food production. This is iodine introduced to the food for reasons other than supplementation. For example, iodine levels in milk are high, because of the use of iodophors as antiseptic cleansing agents in milk production. In developed countries, cow's milk is the major contributor to dietary iodine exposure and, for example, in the UK in 1995 was calculated to contribute 42% of the total intake. In the UK current levels of iodine in milk are of the order of 300 µg/kg although this is subject to seasonal variations.

However, seafood is the most enriched source of iodine in the diet with levels in fish averaging 1000–2000 µg/kg (fresh weight) which is some forty times richer in iodine than most other foodstuffs. Figure B *(above)* shows the typical contribution of different foods to the daily diet in a developed country.

CASE STUDY ONE:

Iodine in Xinjiang Province, China

In the desert region of Xinjiang Province, northwest China goitre prevalence rates are among the highest in the country (40–60%) but the population prefer local rock salt, thus iodised salt programmes have limited success. A new approach based on adding iodine (dripping) to irrigation water had been tested by previous investigators and the present study had the opportunity to examine environmental iodine and impacts on health in three contrasting areas:

Area 1: Agricultural Commune 148	Area 2: Kuqa District	Area 3: Wushi District
Low (3.5%) recent goitre prevalence (20% historic rate)	30% goitre prevalence rate	40–60% goitre prevalence rate
No iodine irrigation	No iodine irrigation	Iodine irrigation
Iodised salt available	Iodised oil programme	Iodised oil programme

Environmental Evaluation

Results show that average soil, wheat and cabbage iodine concentrations are similar in all three areas and are very low by world standards confirming an iodine-deficient environment. Sandy alkaline soils in this region have a poor ability to retain iodine.

In 1999, ten-fold increases in soil water-soluble iodine were reported after dripping in Wushi, however, the results of the present study (year 2000), show that over the longer term, there is little increase in soil or crop levels beyond the natural contents of the non-dripped areas. In contrast, there is a marked difference between the low iodine content of surface drinking waters in Wushi and Kuqa and the very high concentrations in groundwater in AC148 and this dietary source may explain the lower goitre prevalence in this area.

Medical Appraisal

Examinations of 619 schoolchildren show that thyroid volumes are low by all standards reflecting the adequate natural intake (mainly from water) and availability of I-salt in AC148 and the iodination initiatives in Kuqa and Wushi demonstrating the success of these programmes. It is not possible to distinguish the impact of the iodine irrigation alone due to the blanket oil coverage in Wushi and Kuqa.

Thyroid volume and thyroid stimulating hormone (TSH) results are highest in Wushi and lowest in AC148 reflecting the historic goitre picture and are coincident with better nutrition and greater levels of development in AC148 compared to the other more remote areas. Large proportions of the children exceed the recommended upper urinary iodine threshold (300 µg/l). This calls into question the need for iodised salt in AC148 given the high-iodine drinking waters and highlights the potential toxicity problems of blanket oil iodination programmes.

Map showing location of the study areas in China.

Collection of household water, Wushi, China.

Cabbage sampling, Wushi, China.

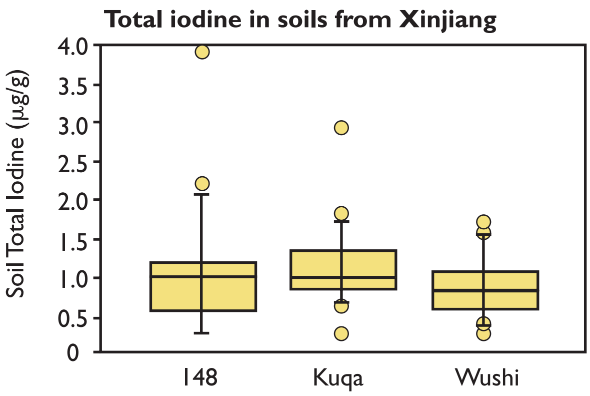
Soil sampling, Wushi, China.

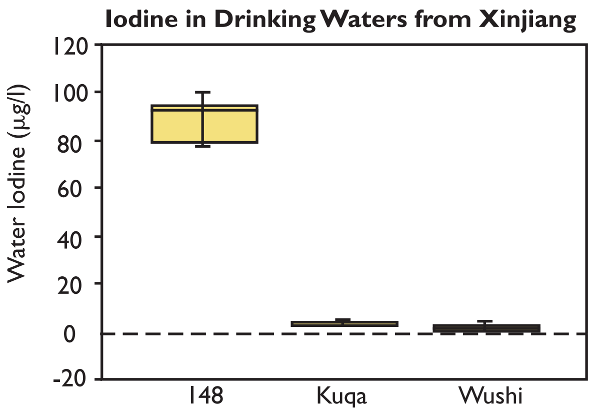
Conclusions

The results of this study suggest that like many other health effects, the risks of IDD decrease with increased development. For areas of the world where marked economic and social development are unlikely to take place over the shorter term, low-cost environmental interventions could be used along side medical techniques to reduce the risks of IDD provided the political will exists to implement these measures.

In many medically driven studies, the iodine deficient state of the population has been superimposed on the local environment without examining the parameters that control the distribution and uptake of iodine via the soil-crop-animal-water-human interface. Although many successful remediation programmes involve iodised salt and oil, these target the human population only and do not address the underlying issue of environmental iodine deficiency. It may be more beneficial, safe and sustainable to improve the iodine content of natural food with spin-off advantages such as increased animal and crop productivity.

Even if, as the results of this study suggest, iodine irrigation is only effective for one or two years it appears to be a very low-cost intervention (US$ 0.12 per person annually). Although, the full socio-economic costs of this and other iodination programmes require further study, in order to maximise the technique in Xinjiang, it is recommended that agricultural practices such as ploughing back straw and manure to the soils to increase the organic matter content and retain iodine should be implemented.





Total iodine in soils and in drinking water from Xinjiang.

Table summarising the iodine status of the environment and population in Xinjiang.

Iodine Content (Mean)	**No.**	**AC148**	**Kuqa**	**Wushi**
Soil Total µg/g	75	1.11	1.16	0.89
Soil Water-soluble µg/g	75	0.015	0.015	0.016
Wheat µg/100g dry weight	75	15.72	14.07	14.28
Cabbage µg/100g dry weight	45	10.94	11.71	11.28
Water µg/l	15	88.65	3.19	1.45
Iodine Status (Mean)	**No.**	**AC148**	**Kuqa**	**Wushi**
Thyroid Volume mls	619	0.53	0.88	1.03
TSH mIU/l	150	1.79	1.31	1.17
Urinary Iodine µg/l	150	464	245	324
% > 300 µg/l I Urine Threshold	150	76	34	56

CASE STUDY TWO:

Iodine in the mountains of Morocco

The Ounein Valley in the Atlas Mountains of Morocco was chosen as a case study area following an earlier investigation by sociologists and nutritionists *(see box)*. This remote mountainous area lies some 150 km inland from the Atlantic coast. The area around Agadir on the coast was selected as a control region so that high and low IDD prevalence environments could be compared. In the Ounein Valley two indices showed that schoolchildren had poorer iodine status than in Igounane near Agadir (Ounein: thyroid volume 18.4 mls, thyroid stimulating hormone 3.0 nmol/l; Igounane: 10.9, 2.5). The enlarged thyroid and the raised hormone level both indicate poorer iodine supply in the remoter Ounein Valley.

In the Agadir area average iodine levels in surface soils are 2.76 µg/g compared to 1.47 µg/g in soils from the Ounein Valley. The water-soluble component of the soil, considered as the mobile bioavailable fraction, is higher in the Agadir area than the Ouenin Valley with average values of 0.12 and 0.04 µg/g respectively. There is three times more 'available iodine' in the soils of the Agadir area than in soils of the high IDD prevalence Ounein Valley. Iodine in soils decreases away from the seacoast although both low and high iodine soils are found in the coastal zone. Although the iodine levels in soils from the Ounein Valley are lower than Agadir, they are not significantly different compared to soils from other parts of the world.

The contrast in iodine status of the two environments is best indicated by iodine in drinking water — 17.8 and 1.6 µg/l for Agadir and Ounein respectively, i.e. a tenfold difference. Interpretation of crop iodine results is limited by the fact that it was not possible to compare like with like. Wheat and barley grains were sampled in the Agadir area whilst vegetables were collected from the Ounein Valley. Beans

'. . . the valley of Ounein, an isolated region in the High Atlas Mountains in Morocco where geography — distance from sea and soil erosion in a mountainous region — fosters iodine deficiency in the form of goiter and limits access of the population to treatment and to education or information concerning the causes and prevention of IDD. A multidisciplinary rural development project in the region began focusing on iodine deficiency after preliminary studies reported that the dietary deficiency of iodine reaches 91.4% in some villages, touching more than 50% of households . . .'

'. . . the under-five mortality rate was 262 per thousand live births in 1991. Because of the dire poverty, high rates of protein-energy malnutrition, poor sanitary conditions and health care, children suffering the most sever micronutrient deficiencies rarely survive to school age in this particular setting.'

Oldham, E A, Barrett, C B, Benjelloun, S, Ahanou, B, and Riley, P J. 1998. An analysis of iodine deficiency disorder and eradication strategies in the High Atlas Mountains of Morocco. *Ecology of Food and Nutrition*, Vol. 37, 197–217.

Village, Ounein Valley, Atlas Mountains, Morocco.

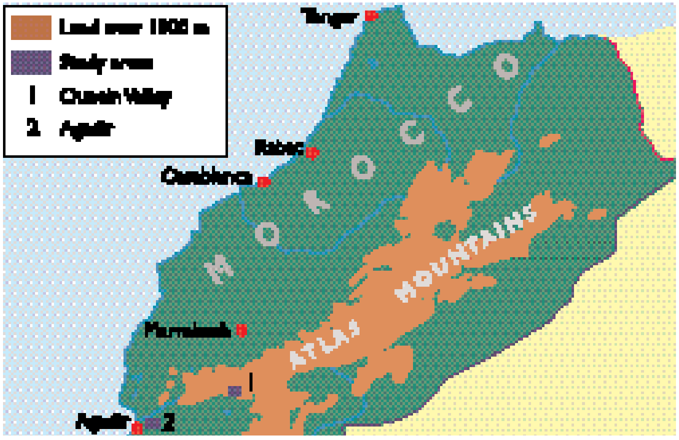
Ounein Valley region, Atlas Mountains, Morocco.

Iodine-rich tins of sardines for sale in the local market.

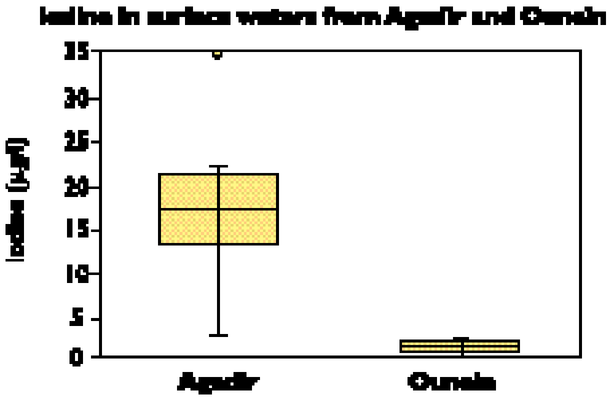
Ultrasound scanning, Ouenin Valley, Morocco.

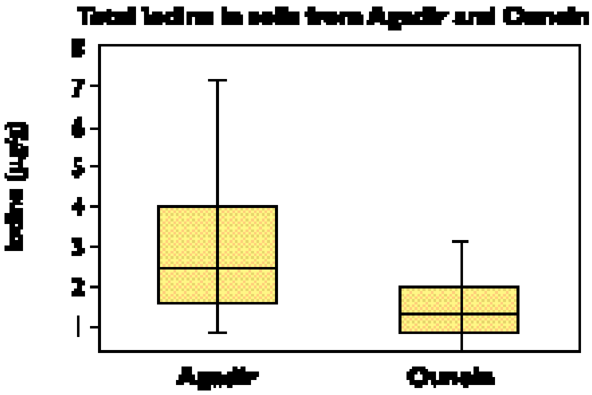
Soil sampling near Agadir, Morocco.

Alkalinity determination of drinking water.



Map showing location of study areas in Morocco.





(mean 9 µg/kg) were consistently found to contain less iodine than carrots (mean µg/kg) grown in the same fields. However, the carrots still only contained 0.75–3.58% of the total soil iodine. The levels of iodine in barley grains ranged from <10–25 µg/kg and the sample of wheat contained 40 µg/kg I (all results for dry matter).

Two iodised salts (80 µg/g I) purchased locally were also determined for iodine and contents were considerably less than that advertised at 12.0 and 3.24 µg/g I. However, even with the lower contents, this salt contributed substantially more iodine to the diet than uniodised salt (0.14 µg/g I). If locals were totally dependent on their immediate environment for providing iodine, then the diet would be substantially deficient, a situation that would probably apply in most non-coastal districts of the world. Poor development with lack of access to external food sources greatly increases the risks of IDD in the local population. Improved road access and development in the region in the past five years has clearly reduced the risks. Because most of the Ounein Valley is dependent on irrigation to grow crops, the addition of iodine to irrigation waters could potentially help improve the environmental iodine status. However, the poor sandy soils of the area with little organic matter have little ability to fix iodine, whether it be natural iodine deposited from the atmosphere or iodine added to irrigation waters.

STRATEGIES

Environmental strategies for reducing risks

History and statistics demonstrate that urbanisation and development help reduce the risks of IDD. Whilst improvement of a nation's health and nutrition can be considered as one of the driving forces behind industrialisation and development, it is not usually the prime reason but a result of such changes. It includes an increased level of iodine in the diet, primarily due to foodstuffs originating from outside the local environment. Furthermore, increased food processing as a result of development will involve more sources of adventitious iodine in the diet (iodine added to food but not for the purpose of supplementation). Examples of this are: the iodine content of poultry and eggs increased by the use of fish flour as chicken food; iodates used as oxidants and a sanitising agent in bread making; the use of iodophors as antiseptics in the dairy industry; and the iodine-rich red food colouring erythrosine.

When there is no prospect of development, or where it neglects remote rural areas, other measures are required to reduce the risks of IDD. These can be classified as medical intervention and environmental solutions. Medical intervention techniques bypass natural means of delivering iodine by enhancement in the things we eat or drink (principally salt) or directly, such as by an injection of iodised oil. This project has sought alternative environmental techniques that can be used to compliment medical intervention where such methods are inappropriate or ineffective due to a combination of cultural, social, political, economic and legal forces. These forces are every bit as critical as the pathology, physiology and pharmacology behind the medical measures, or the geochemistry involved in environmental solutions and need further examination.

A strategy based on controlling iodine in the environment requires a two-fold approach. Firstly, the iodine already present needs to be managed more effectively. However, there are many regions of the world where the levels are so low that even effective management will not yield adequate amounts for the local population. Secondly, in such instances, iodine in the environment needs to be increased, this not only benefits the population but can enhance agricultural (crop and animal) productivity, an advantage that medical interventions cannot achieve by targeting people directly. In order to deliver maximum benefit to the local population, over a prolonged period of time, iodine added to the environment also has to be managed effectively.

Iodised and non-iodised table salt, Morocco.

School in AC148, China.

Rock salt, the preferred local source of iodine, China.

Deep water sources tend to be more iodine-rich.

Locally grown corn, China.

Site of iodine dripping in Wushi, China.

Efficient management of the environment's natural iodine

Changes in agricultural practices will modify the environment's ability to retain iodine and the subsequent pathways through the food chain. From our knowledge of the geochemical behaviour of iodine in the surface environment we propose the following strategies:

- *Changing crops grown.* Leafy vegetables appear to concentrate available iodine better than grains;
- *Using livestock grazing to concentrate iodine.* Meat and diary products are generally richer in iodine than other foodstuffs, probably due to livestock acting as concentrators of iodine precipitated from the atmosphere onto the pasture which they graze;
- *Improving the soil's ability to fix iodine.* Organic matter retains iodine, so the addition of such materials already rich in iodine (seaweed or peat) will significantly increase levels. Changing the soil's texture from sandy to silty or clayey should also help to retain more iodine;
- *Making the iodine more available.* Fixing more iodine in the soil is desirable, but to reach the food chain iodine has to be bioavailable such as the volatile and mobile forms I^- and I_2. This can be achieved by: low soil pH and high Eh; high level of microbial and root activity; and adequate pathways within the soil to allow migration of iodine (i.e. uncompacted soil with abundant pore space);
- *Reducing iodine volatilisation loss from the soil-plant system.* There is evidence that much iodine can be lost from the soil-plant system through volatilisation. To prevent this, measures opposite to those that make the iodine more mobile are needed. Liming the soil (i.e. increasing its alkalinity) appears an effective way of immobilising iodine;
- *Finding alternative sources of iodine-rich water.* Deeper water sources are frequently more enriched in iodine, as seen in our Xinjiang case study;
- *Preventing the removal of iodine by flooding.* It may be desirable to reduce the number of flooding events since, although these mobilise and increase iodine bioavailability, in the long term they lower the soil iodine status in soils without regular repletion.

The management of soil iodine as described is extremely complex and certain factors that are beneficial (e.g. flooding increases iodine bioavailability) can also be seen to have deleterious effects (e.g. flooding removes soil iodine). In marginal areas good management of the land will use available iodine efficiently and could make a significant difference in determining whether or not a population becomes iodine-deficient. Such procedures should always be considered in measures to reduce the risks from IDD.

However, in areas of significant iodine-deficiency, where the local population have little or no scope for managing their own environment because of extreme poverty and harsh conditions, adding iodine from an outside source is the only practical approach. Nonetheless, the measures discussed above are still important because any technique that adds iodine to the environment needs to use this essential trace element efficiently and not lose it through surface waters or volatilisation to the atmosphere.

STRATEGIES continued:

Adding iodine to the environment

- *Iodination of irrigation water.* The low cost and success of this method has been demonstrated by the Kiwanis International sponsored iodine-dripping project in Xinjiang Province, China, where our project carried out further studies. However, the long-term impacts and costs need to be fully assessed, particularly with regard to the soil's ability to retain added iodine.
- *Adding iodine to drinking water supplies.* This project has underlined the importance of drinking water in the dietary intake of iodine, particularly in areas where food is locally grown and there are few adventitious sources of iodine in the diet. Iodine has been added to municipal water supplies in Sicily. In several African trials iodine has been introduced to wells by slow releasing iodine-impregnated wood or silicon matrix systems.
- *Fertilisers.* Chilean nitrate (80 µg/g I) fertilisers or seaweed ash (11 100 µg/g I) are a good means of raising soil iodine status. A further interesting strategy could be to encourage the local population to grow boxes of a food supplement (e.g. cress) in soils with an iodine-rich fertiliser or brine.

PROJECT OUTPUTS

Technical Reports and Publications

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PROJECT OUTPUTS continued:

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What do you mean by iodine deficiency? A geochemical perspective. IDD Newsletter, (2003). International Council for the Control of Iodine Deficiency Disorders (ICCIDD). May 2003.

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Soil, wheat, cabbage and drinking water iodine in relation to human iodine status and iodine deficiency disorders in Xinjiang Province, China. Accepted for presentation to the 6th International Symposium on Environmental Geochemistry, Edinburgh, 7–11 September 2003.

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Controlling the health disorders of iodine: translating geochemistry into health. Accepted for presentation to the 6th International Symposium on Environmental Geochemistry, Edinburgh, 7–11 September 2003.

More Information about the project and its outputs can be found on the project web site at: **http://www.bgs.ac.uk/dfid-kar-geoscience/idd/**

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