Review

# The development of a global program for the elimination of brain damage due to iodine deficiency

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Iodine deficiency is the most common preventable cause of brain damage with more than 2 billion people from 130 countries at risk. The global problem of iodine deficiency has been redefined by a readily transmitted population concept, with an easy acronym – the concept of the iodine deficiency disorders (IDD) – referring to all the effects of iodine deficiency in a population, that can be totally prevented by correction of iodine deficiency with special emphasis on brain damage and not just to goitre and cretinism (1983). This was followed by the creation of the International Council for Control of Iodine Deficiency Disorders (ICCIDD) supported by WHO and UNICEF with 700 multidisciplinary professionals from more than 100 countries, committed to providing technical assistance to national programs for the elimination of IDD (1986). The WHO policy of Universal Salt Iodization (USI) has been widely adopted which requires iodization of all food for human and animal consumption by the use of iodized salt (25-40 mg I/kilo). Simple practical methods for monitoring – by the measurement of salt iodine and urine iodine were developed and promoted on a large scale with the technical assistance of the ICCIDD.

**Key Words: brain, ICCIDD, IDD, iodine deficiency disorders, monitoring, salt iodization, USI**

## INTRODUCTION

Iodine deficiency is considered to be the most common cause of preventable brain damage in the world.[1] The problem arises when people live in an environment where the soil has been leached of iodine, either due to flooding of river valleys or by high rainfall or glaciation in hilly mountainous areas. The deficiency in the soil leads to deficiency in all forms of plant life including cereals, grown in the soil. Hence large populations living in systems of subsistence agriculture particularly in the developing countries, as in the great river valleys of Asia, are locked into the risk of iodine deficiency.[2]

Iodine is an essential element for human and animal development because it is a constituent of the thyroid hormones, thyroxine ($T_4$) and triiodo-thyronine ($T_3$). In a person affected by iodine deficiency, as the thyroid gland tries to maintain the level of thyroid hormones in the blood, it enlarges to form a goitre. But eventually it fails to maintain the hormone levels, with damaging effects on the development of the brain and other organs. The relation between iodine deficiency and brain damage was originally proposed after studies showed the association between goitre and mental retardation (endemic cretinism). Later there was controversy about whether cretinism was related to iodine deficiency, until a controlled trial with iodized oil in Papua New Guinea established that cretinism could be prevented by correction of iodine deficiency before pregnancy.[3,4] The apparent spontaneous disappearance of cretinism in Europe was attributed to 'silent' correction of iodine deficiency by gradual dietary diversification together with the gradual use of iodine supplements associated with economic and social development.[5] Studies with animal models (sheep, marmoset monkey and rat) confirmed that iodine deficiency caused retardation of foetal brain development.[6] The combination of the controlled trial and the results of the studies in animal models clearly established that prevention of brain damage could be achieved by correction of iodine deficiency before pregnancy.

## IODINE DEFICIENCY DISORDERS (IDD)

The results of the research required a re-conceptualization of the effects of iodine deficiency from the common lump in the neck (goitre) to include a spectrum of consequences. These include stillbirths as well as neonatal and other types of hypothyroidism, but the most important effect is that of foetal brain damage. To this end, the term iodine deficiency disorders (IDD) was proposed [7] and supported by a Lancet Editorial [8] and has since been generally adopted throughout the world, including adoption by the Chinese without translation. The term IDD refers to all effects of iodine deficiency on growth and development in a human and animal population, which can be prevented by correction of the deficiency. Effects on brain function occur at all stages of life, from foetal damage to the effects of hypothyroidism in the neonate, child or adult (Table 1).

Social and economic effects result from iodine deficiency in both human and animal populations. In humans

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**Table 1.** The Iodine Deficiency Disorders (IDD) †

| | |
|---|---|
| Foetus | Abortions<br>Stillbirths<br>Congenital Anomalies<br>Increased perinatal mortality<br>Neurological cretinism:<br>*mental deficiency, deaf mutism, Spastic diplegia, squint Neurological Cretinism*<br>Hypothyroid cretinism:<br>*mental deficiency, dwarfism, hypothyroidism*<br>Psychomotor defects |
| Neonate | Neonatal hypothyroidism |
| Child and Adolescent | Retarded mental and physical development |
| Adult | Goitre and its complications<br>Iodine Induced Hyperthyroidism (IIH) ‡ |
| All Ages | Goitre<br>Hypothyroidism<br>Impaired mental function<br>Increased susceptibility to nuclear radiation |

†Hetzel [2, 7,]

‡Transient following iodization, minimized by reduced rate of increase in iodine intake

there is reduced school performance in children and reduced productivity in adults. Detailed calculations were made of the economic costs of medical assessment and treatment of goitre in Germany where there was still much uncontrolled IDD. The yearly costs of diagnosis were estimated at US$250 million, of treatment at US$300 million, of hours lost in working time for this medical care at US$150 million, resulting in a total of US$700 million a year.[9] There are also significant effects on all livestock with impaired reproduction in poultry, sheep, goats and cattle, with reduced wool growth and milk production and reduced rates of survival in the offspring. Such effects indicate that correction of iodine deficiency has direct economic benefits.[10] The World Bank calculated that each dollar dedicated to IDD prevention would yield a productivity gain of $28.[11]

## THE MAGNITUDE OF IDD

WHO estimated that there were in excess of 2.2 billion people from 130 countries at risk of IDD in the mid 90s (Table 2). These countries include the most populous–Bangladesh, Brazil, China, India, Indonesia and Nigeria (ICCIDD/WHO/UNICEF 1999). With the recognition that even mild iodine deficiency in the mother has effects on the rapidly growing foetal brain continuing into the first three years, and that these early effects, although preventable, are not reversible[3,4,] this global scourge is of such great magnitude, that it provides one of the major challenges in international health.[12]

## BRIDGING THE GAP BETWEEN RESEARCH AND ITS APPLICATION

There was an urgent need to bridge the great gap between research on the subject of iodine deficiency and brain damage and its application in public health programmes throughout the world. A beginning was made with a Symposium in 1983 at the 4th Asian Congress of Nutrition in Bangkok, which agreed on the need for public health action.[13] Subsequently in response to an invitation to the Australian Government from the United Nations Administrative Committee on Coordination Sub-Committee on Nutrition (ACC/SCN), a report with a proposal for a global prevention programme was prepared and submitted to the ACC/SCN early in 1985. The report included a global review of the scientific evidence, a model for a national programme and a proposal to establish the International Council for Control of Iodine Deficiency Disorders (ICCIDD). The Council would serve as an expert NGO available to agencies and government to assist in the development of national programmes. This proposal was accepted by the ACC/SCN in 1985 with subsequent publication.[14]

## INTERNATIONAL COUNCIL FOR CONTROL OF IODINE DEFICIENCY DISORDERS (ICCIDD)

The ICCIDD, an international multidisciplinary network formed in 1985 with support from UNICEF, WHO and the Australian government, aims to bridge the gap between the research and its application in national programmes. The ICCIDD now comprises more than 700 multidisciplinary professionals from 100 countries with a majority from developing countries. The disciplines include endocrinology, nutrition, epidemiology, laboratory technology, salt technology, education, mass media and public health administration.

At the inauguration of the ICCIDD in Kathmandu in 1986, letters of support were received from the Director

**Table 2.** Current Estimates of Population at risk of IDD by WHO Regions†

| WHO Region | Number of Countries with IDD | Total population in IDD affected countries | At Risk Population‡ | |
|---|---|---|---|---|
| | | Millions | Millions | % of the Region§ |
| Africa | 44 | 610 | 295 | 48% |
| Americas | 19 | 477 | 196 | 25% |
| South-East Asia | 9 | 1,435 | 599 | 41% |
| Eastern Mediterranean | 17 | 468 | 348 | 74% |
| Europe | 32 | 670 | 275 | 32% |
| Western Pacific | 9 | 1,436 | 513 | 31% |
| TOTAL | 130 | 5,096 | 2,226 | 38% |

†Based on UN population Division (UN estimates 1997)

‡The at risk population is the population living in iodine deficiency areas where total goitre rate (TGR) is more than 5%

§ Expressed as a percentage of the total population in the Region[26]

General of WHO (Dr Halfdan Mahler) and the Executive Director of UNICEF (Mr James Grant). A Symposium was held covering all aspects of the global problem including global epidemiology with reference to all the WHO Regions, technical aspects of control programmes and proposal of a global strategy.[15] The ICCIDD was formally recognized in 1987 as the expert group on all aspects of iodine deficiency disorders (IDD) by the UN System through the ACC/SCN. In 1987 the ACC/SCN also established an IDD Working Group of multilateral and bilateral agencies involved in nutrition programmes, and it was to this group that the ICCIDD reported each year, as well as to WHO and UNICEF. In 1990 a Global Action Plan[18] for the elimination of IDD by the year 2000 was proposed to the ACC/SCN by the ICCIDD, which provided for actions at the global, regional and national level. This plan was endorsed by the ACC/SCN (1990).[16] In 1994 the ICCIDD was officially recognized by WHO as an NGO working collaboratively towards the elimination of IDD by the year 2000.

From its foundation the ICCIDD chose technical assistance to national programmes as the first priority. This led to a working relationship with the governments of IDD affected countries (usually Ministries of Health), with the leading international aid agencies WHO and UNICEF, and, more recently, with the salt industry. Important workshops on the assessment of IDD were held with WHO and UNICEF in 1994 and 2001.[17,18,]

## WORLD HEALTH ASSEMBLY

The 1986 World Health Assembly (WHA), with representation from more than 160 governments, passed a Resolution initially sponsored by Australia, which recognised the importance of iodine deficiency as a cause of brain damage and the need for effective programmes of prevention and control.[19]

This was followed by WHA Resolutions in 1990, calling for the elimination of IDD by the year 2000 and a later Resolution in 1996, calling for sustainability of the programme through systematic monitoring. Both included reference to the role of the ICCIDD and its availability to assist countries.[20, 21,]

## WORLD SUMMIT FOR CHILDREN

The endorsement of the Global Action Plan was followed by adoption of the goal of virtual elimination of IDD by 2000 by the World Summit for Children on September 30th 1990, at a special meeting at the United Nations, New York. [22] This meeting was attended by 71 Heads of State who signed a declaration providing 27 new goals for improved health and education for all children throughout the world (World Summit for Children 1990). This Declaration was subsequently signed by representatives of 88 other national governments. Such a resolution was unprecedented and has since provided very important political support for national IDD programmes throughout the world. Following the World Summit, UNICEF proposed a middecade goal (1995) that all countries with an IDD problem should by this time have established a National Council for the Control of IDD and a separate control unit to initiate a salt iodization programme.

## UNIVERSAL SALT IODIZATION (USI)

The massive global problem of iodine deficiency has been met at the technological level by the iodization of salt. This measure had been shown to be effective in a number of industrialized countries. Prior to 1990 few developing countries had large scale iodization programmes and it was estimated that less than 20% of salt was iodized.[23] This has changed following the adoption of the policy of Universal Salt Iodization (USI) by the Joint UNICEF/WHO Committee on Health Policy (1994).[24] USI requires that all food grade salt for human and animal consumption be iodized.[25] This requires legislation. However, appropriate legislation did not always follow. The recommended level is 20-40mg iodine per kilo of salt. The addition of this amount of potassium iodate can be made with a greatly reduced salt intake if necessary.

## THE GLOBAL PARTNERSHIP

An extended informal global partnership has developed over the years. This partnership includes the people, governments and salt industry of IDD affected countries; the international agencies WHO and UNICEF, the World Bank, the bilateral aid agencies and the technical agencies; the ICCIDD, MI, PAMM (Program against Micronutrient Malnutrition, now Emory University), the salt industry and Kiwanis International. The establishment of the Network for the Sustained Elimination of Iodine Deficiency occurred in 2002 in collaboration with the international salt industry.

## DEVELOPMENT OF NATIONAL PROGRAMMES

A significant factor in the development of national programmes between 1987 and 1998 has been a succession of annual regional meetings held throughout the world over 20 years by the ICCIDD with the collaboration of WHO and UNICEF. These meetings have been attended by representatives from Ministries of Health and other important sectors such as the salt industry and media in relation to the national programmes.

It is through these regional meetings for review of national programmes that the limited number of experts from the ICCIDD network, have been able to communicate with professionals from many countries. This has subsequently led to consultancies and further contacts designed to identify and subsequently remove obstacles to progress. The expertise required includes epidemiology, the establishment of laboratories (salt iodine, urine iodine), advice regarding planning, education and communication, management, iodized salt and other iodine technologies. This is why the ICCIDD multidisciplinary network has been developed to assist countries.

A series of ICCIDD/WHO/UNICEF Regional Reports (covering all six WHO regions) have been published. Notable progress has occurred in Africa. At the first African Regional meeting (Yaounde, Cameroon in 1987), only 22 countries were represented. At this time an IDD Task Force for Africa was established by the ICCIDD with WHO and UNICEF to promote national programmes. In 1996, 45 countries were represented including Angola, Eritrea, Mozambique and Republic of the Congo in spite of the occurrence of civil war in these countries. There

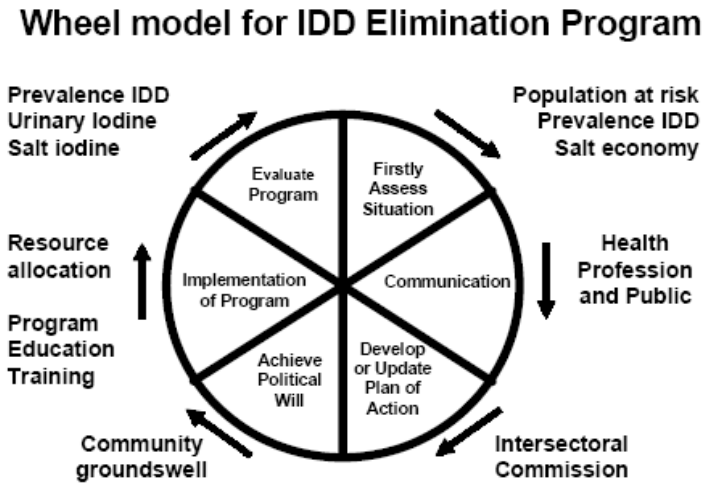


**Figure 1**[18]. 1. Assessment of the situation requires baseline IDD prevalence surveys, including measurement of urinary iodine levels and an analysis of the salt economy. 2. Communication of findings to health professionals and the public, so that there is full understanding of the IDD problem and the potential benefits of elimination of this most common preventable cause of brain damage. A community education campaign is required to educate all age groups about the effects of iodine deficiency with particular emphasis on the brain. 3. Development of a plan of action includes the establishment of an inter-sectoral committee or commission on IDD and the formulation of a strategy document on achieving the elimination of IDD. 4. Achieving political will requires intensive education and lobbying of politicians and other opinion leaders. 5. Implementation needs the full involvement of the salt industry. Special measures, such as negotiations for monitoring and quality control of imported iodized salt, are required. It will also be necessary to ensure that iodized salt delivery systems reach all affected populations, including the neediest. In addition, the establishment of cooperatives for small producers, or restructuring to larger units of production, may be needed. Implementation will require training at all levels in management, salt technology, laboratory methods and communication. 6. Monitoring and evaluation require the establishment of an efficient system for the collection of relevant scientific data on salt iodine content and urinary iodine levels. This includes the establishment and the maintenance of suitable laboratory facilities.

has been significant progress in country programmes in Africa since 1987, including the Republic of the Congo.

## THE SOCIAL PROCESS MODEL

At these regional meetings a 'wheel' feedback model for a national programme has been presented to show the social process involved, as shown in Figure 1.[5] The model shows the diversity of functions that have to be linked together to achieve an integrated successful national IDD elimination programme, and involves six components clockwise in the hub of the wheel. Three key elements in the Social Process Model are: a national inter-sectoral coordinating body, commission or coalition; a plan of action for the elimination of IDD; and legislation on salt iodization. The 'wheel' model is driven by the 'marker' of salt iodine consumption and the urine iodine excretion of the community or population. Urinary iodine excretion provides an excellent indication of iodine intake, and can be easily assessed using the median level from a sample of just 40 subjects from each local community. These markers have provided the essential elements for monitoring the programme to assess whether iodine deficiency is being eliminated. Determinations should be carried out regularly every year. If there is evidence of inadequacy of iodine intake through iodized salt then appropriate measures can be taken at factory, retail or household level.

Measurements of urinary iodine have usually been carried out in children aged 8-12 years taking advantage of their availability in the school setting. However, if school attendance is reduced (through distance or poverty) then this must be followed up by sampling at the household level.

Another community group of great importance to the elimination programme are women of reproductive age, particularly including pregnant and breastfeeding women. These groups should receive special attention, for example as has been done in China where comprehensive data are now being collected.

The availability of the salt iodine and urine iodine determinations suitable for large-scale use is a great strength for the National IDD Elimination Programme. The effectiveness of the social process can be reliably and readily assessed through these determinations. Adequate resources must be provided for iodine measurements by funding trained manpower, equipment and materials.

## CRITERIA FOR MONITORING PROGRESS

The criteria for monitoring progress towards sustainable elimination of IDD as a public health problem were originally determined by a Joint WHO/ UNICEF/ICCIDD Working Group on Assessment and Monitoring of IDD in 1994.[24] They were endorsed at the subsequent meeting in 2001. (Table 3)[18]

## REPORT ON PROGRESS IN NATIONAL PROGRAMMES

In 1999 ICCIDD in collaboration with WHO and UNICEF published a report which reviewed the IDD global situation with reference to national programmes, and provided an evaluation of progress from 1986 to 1997.[26] According to the report, following the promotion of the goal of elimination of iodine deficiency, legislation on iodized salt and the sensitization of the salt industry, there had been a big increase in the consumption of iodized salt

**Table 3.** WHO/ICCIDD/UNICEF criteria for monitoring progress towards eliminating IDD as a public health problem†

| Indicator | Goal |
|---|---|
| 1. Salt iodization | |
| Percentage of households consuming effectively iodized salt | >90% |
| 2. Urinary iodine | |
| Proportion below 100µg/L | <50% |
| Proportion below 50 µg/L | <20% |
| 3. Thyroid size | |
| In School children 6-12 years of age: | |
| Proportion with enlarged thyroid (by palpation or ultrasound) | <5% |
| 4. Neonatal TSH | |
| Percentage with levels >5U/L whole blood | <3% |

† WHO/UNICEF/ICCIDD[18]

**Table 4.** Monitoring of Household Consumption of Iodized Salt†. Current Status of Monitoring and Laboratory Facilities

| WHO Region | Number of countries with IDD | % Household consumption | Monitoring salt quality | Monitoring iodine status |
|---|---|---|---|---|
| Africa | 44 | 63% | 29 | 24 |
| Americas | 19 | 90% | 19 | 19 |
| South-East Asia | 9 | 60% | 8 | 7 |
| Eastern Mediterranean | 17 | 66% | 17 | 13 |
| Europe | 32 | 27% | 14 | 10 |
| Western Pacific | 9 | 76% | 8 | 6 |
| Total | 130 | 68% | 95 | 79 |
| | 100% | | 73% | 61% |

† ICCIDD/WHO/UNICEF[26]

with global coverage of 68% of households in 1997 (Table 4). This compared with less than 20% before 1980 with only spasmodic efforts and no sustained commitment by governments to national programmes. All regions, except Europe, had achieved 60% or more but Europe had achieved only 27%. The poor achievement of Europe with only 27% coverage is correlated with the inadequate facilities for the monitoring of salt iodine and urine iodine. Of 130 IDD affected countries, 105 (77%) had national inter-sectoral bodies in place. Ninety eight (75%) had legislation on salt iodization in place and a further 12 had it in draft form. This indicates substantial progress with the establishment and functions of national programmes.

## FACTORS IN SUCCESS

This global program for the elimination of brain damage due to iodine deficiency provides a model that could be applicable to a variety of other health, social and environmental problems. The former Director General of the WHO (Dr Gro Brundtland) has pointed out that the achievement of IDD elimination "will be a major and total public health triumph ranking with small-pox and polio". It will be a major global triumph in the elimination of a non-infectious disease.[27] Some of the principal factors that I consider responsible for this success are:

1. The Virtual Elimination of Iodine Deficiency Disorders by the year 2000 was included in the 27 goals accepted by the World Summit for Children in 1990.[22] The World Summit provided major political support for National IDD Elimination Programmes.
2. The WHO/UNICEF policy of Universal Salt Iodization (USI) requires iodization of all food for human and animal consumption by the use of iodized salt (25-40 mg I/kilo). The salt industry has also accepted and adopted this intervention as a permanent organized measure.
3. The global problem of iodine deficiency was redefined by a population concept, with an easy acronym – the concept of the iodine deficiency disorders (IDD) – referring to all gradations of the effects of iodine deficiency in a population, that can be totally prevented by correction of iodine deficiency with special emphasis on brain damage and not just to goitre and cretinism.
4. The International Council for Control of Iodine Deficiency Disorders (ICCIDD) supported by WHO and UNICEF with 700 multidisciplinary professionals from more than 100 countries, has provided technical assistance to national programs for the elimination of IDD as well as advice at global level on scientific issues.
5. Simple practical methods for monitoring –the measurement of salt iodine and urine iodine have been made effective for use on a large scale with the technical assistance of the ICCIDD.

## ADDENDUM

Update since 2000. The latest IDD Newsletter (February 2012) included a Report from UNICEF with data on global iodine nutrition for 2003, 2007 and 2011.[28]

Over two thirds of the world population is now covered by iodized salt - the number of iodine deficient countries has decreased from 54 in 2003 to 47 in 2007 and 32 in

2011. This is described as 'a remarkable leap forward in the past decade'.

**ACKNOWLEDGEMENTS**

I acknowledge the work described was the outcome of a new NGO, The International Council for Control of Iodine Deficiency Disorders (ICCIDD) officially recognised by WHO and UNICEF dating from 1986 when it was formally created at a Founding Meeting in Kathmandu, Nepal (23-28 March 1986). The ICCIDD consists of 700 multidisciplinary professionals from 100 countries with a majority from developing countries.

I was Executive Director (1986-1995) after which I became Chairman (1995-2001) and now Emeritus Chair.

In 1994 the ICCIDD was officially recognised by WHO as an NGO working collaboratively towards the elimination of IDD by the year 2000.



**AUTHOR DISCLOSURES**

I declare no conflict of interest. Funding for the ICCIDD has been from WHO, UNICEF, World Bank, AusAID, CIDA and the Dutch Agency for International Development. ICCIDD Annual Reports are available from 1986.

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# 發展全球計畫以消除因碘缺乏所導致的腦損傷

碘缺乏是造成腦損傷中常見且可預防的原因，在 130 個國家中有超過 20 億人有此風險。全球性碘缺乏問題已被用一個較容易傳達的族群觀念重新定義(1983 年)，也就是用簡單的字母縮寫- IDD(碘缺乏疾病群)的觀念。IDD 是指族群中碘缺乏的所有後果，是可藉由改正碘缺乏來完全預防，特別強調在腦損傷而不只是甲狀腺腫和呆小症。接著 1986 年由世界衛生組織和聯合國兒童基金會支持而創立國際碘缺乏疾病控制委員會 (ICCIDD)，成員為來自 100 多個國家的 700 位各領域的專家，旨在提供各國技術性的協助，以消除碘缺乏疾病。世界衛生組織的全面食鹽加碘(USI)政策已被廣泛採用，以每公斤食鹽中添加 25-40 毫克碘的方式，使人們和動物攝取的所有食物中含碘。在國際碘缺乏疾病控制委員會技術協助下，能在大量樣本實施的簡單可行監測方法-測量食鹽的含碘量及尿液中的碘，已被發展並推動。

**關鍵字：腦、國際碘缺乏疾病控制委員會、碘缺乏疾病、監測、食鹽加碘、全面食鹽加碘計劃**