EXPERIENCE WITH ENVIRONMENTAL SUPPLEMENTATION OF IODINE IN IRRIGATION WATER AS A PRACTICAL AGRICULTURAL APPROACH TO REDUCE IODINE DEFICIENCY

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Contents

Summary

Our studies and those of others have amply documented that the growth and mental ability of children is markedly increased by iodine supplementation of previously deficient populations. In southern Xinjiang, iodine supplementation of women of child-bearing age produced an increase in the mean intelligence quotient of their offspring of fully one standard deviation. In addition, infant mortality has been decreased by 58% by iodine supplementation. These are remarkable results, and are not unique; similar results have been documented wherever severe iodine deficiency has been eliminated.

Such results are a great spur to efforts to eliminate this anachronistic scourge. Up until now, agriculture has had little active involvement in iodine supplementation except for iodination of livestock. The experience documented in this article suggests that in some circumstances, agriculture may be able to play a larger and important role in iodine supplementation. The iodine dripping experience affords one successful example of the utilization of agriculture and food to provide missing micronutrients.

Our experience with agriculture-based approaches to iodine supplementation leads us to certain tentative conclusions:

a. The last reservoirs of IDD are remote, out-of-the-way places that are rural and outside commercial networks, to a large degree. This is true in inner Asia, and probably in Africa and perhaps parts of South America as well. In these areas IDD is flourishing, still. This is where cretins occur and children are born retarded because of iodine deficiency. These areas need special attention, and often special treatment, to achieve adequate iodine supplementation. These areas constitute an essential and indeed central focus of IDD eradication in the coming years.

b. Corresponding to the rural and non-commercial characteristics of these societies, we have envisioned, and partly implemented, an agriculture-based approach to iodine supplementation in such areas. It now appears possible to have a two-part agriculture-based program against IDD in central Asia and perhaps in other rural developing areas as well. Both parts are firmly based on the local agricultural economy, and both utilize the food chain to achieve iodine delivery:

c1. Where irrigation is primary, iodine dripping into irrigation canals can supplement or replenish iodine in the soil. This iodine is then available to crop plants, animals, and the human population for a number of years (up to 6 years, how many more years is not yet known). This technique has been applied extensively (reaching a population of 2.6 million) in Xinjiang during the past seven years, and has been successful. It more than pays for itself each year in increased animal production. Areas where it may be applicable include the Ferghana Valley of Uzbekistan and Kirghizstan, northern Pakistan, Mali in Africa, and perhaps others.

c2. In pastoral or grazing, nomadic or semi-nomadic societies, generous iodination of salt licks for animals may increase the animals' productivity and provide iodine supplementation for the people eating animal products, especially milk. In such societies, as in Tyva, about 70 per cent of food is animal-based (chiefly milk and meat). Milk is an efficient agent to transfer iodine, and in these societies, virtually everyone consumes it regularly, as yogurt, fermented mare's milk, etc. So the needs of this type of rural population may be met with an agriculture-based solution. This would apply to Tyva and its neighboring republics, Mongolia, Inner Mongolia, Tibet, and perhaps more widely. None of these areas have effective treatments at present. They are on the fringe—but they suffer severe and so far uncontrolled iodine deficiency.

As iodine deficiency is progressively limited to remote areas of the world, these areas must become the focus of efforts to eliminate this scourge. This can only be achieved by direct involvement and experience in such areas. Innovative approaches may be necessary, depending on the conditions and circumstances of individual areas. In such areas, an agriculture-based approach may be attractive, and indeed may be the only feasible approach to providing iodine to the entire community. The possibilities of such an approach are illustrated by the experience with the iodination of irrigation water and the promise of iodination of herd animals in pastoral societies. Since agricultural supplementation most closely approximates the condition in iodine-sufficient environments, it has possible attractions for more widespread use.

1. Introduction

Iodine deficiency is the most widespread and medically important micronutrient deficiency known. Iodine deficiency causes a wide spectrum of human ills, including fetal wastage and infertility; infant mortality; endemic cretinism characterized by mental retardation, deaf mutism, and spasticity; growth failure; impaired intelligence; goiter and hypothyroidism. These are collectively termed "iodine deficiency disorders" or IDD. Iodine deficiency impairs the development of the child's brain and musculoskeletal system, and also appears to impair development of the immune system, thus accounting for a great increase in infant mortality found in iodine deficient areas. In areas of severe endemic iodine deficiency, the incidence of goiter may exceed 60 per cent of the population, cretinism may occur in up to 8 percent or more of the population, and the mean intelligence quotient of the population may be lowered by 15 percent. Iodine deficiency occurs because of a lack of iodine in soil, related to geologic and geographic factors. It is estimated that 1.5 billion people are at risk of iodine deficiency worldwide. The elimination of iodine deficiency is an essential part of economic and social development in the developing world, ensuring a more intelligent and healthy population. People eat iodized salt mainly as a means of prevention, not treatment. Consuming iodized salt reduces the risk of disorders from iodine deficiency, most important among them brain damage, in the next generation.

In general, the best treatment approach is through iodizing the salt supply for humans and farm animals, although in some circumstances other techniques are needed. Attention to the problem has increased greatly in the last quarter-century, and the major world health organizations have adopted the goal of eliminating iodine deficiency worldwide by the year 2000. The global elimination effort of universal salt iodization is driven by the pledges made by the Member States of the UN. Indeed, great strides have been made. Although the goal has not been reached, the world is approaching the goal of universal salt iodization: by the end of 1999, more than 70% of households in the world had access to iodized salt as demonstrated by national survey data consolidated by UNICEF. Due to the nature of the problem, preventing recurrence of iodine deficiency disorders requires sustained work and attention, and is a joint responsibility of public, private and civic organizations.

2. Basic Pathophysiology and Manifestations

Iodine deficiency impedes thyroid hormone synthesis, since each hormone molecule contains four atoms of iodine. Deficiency of thyroid hormone is the sole known effect of iodine deficiency. Thyroid hormone is an essential hormone in all vertebrates, and is the principal hormone controlling development. In humans, iodine deficiency is responsible for the wide range of pathological effects collectively known as Iodine Deficiency Disorders, depending on the timing and severity of the deficiency. The most severe consequences affect fetal development and are manifested as fetal and infant mortality, and impairment of brain development causing mental retardation, deaf-mutism and spasticity. In endemic areas, a high percentage of newborn infants are born with congenital hypothyroidism, which if continued, results in mental retardation. Mental retardation caused by thyroid hormone deficiency is called cretinism; when caused by iodine deficiency it is called endemic cretinism. Worldwide, iodine deficiency is thought to be the commonest preventable cause of mental retardation. Less severe degrees of iodine deficiency, not producing frank cretinism, cause impairment of intelligence and psychomotor abilities and of physical growth in affected populations. Finally, iodine deficiency is responsible for goiter (pathological enlargement of the thyroid gland) and hypothyroidism in children and adults.

3. Geology and Geography of Iodine Deficiency

Humans normally get iodine from food, both from animals and crops; the latter get iodine from the soil. It is estimated that humans get 90% of their iodine from food, and 10% from water. Iodine deficiency in humans and animals results from iodine deficiency in soils, a condition found widely on every continent. The occurrence and location of iodine deficiency is dependent on geologic and climatic conditions favoring leaching of iodine from surface soil over geologic time. Thus, it is found in mountainous and other regions subject to heavy glaciation (e.g., the Alps, Andes, and Himalayan mountains, and in the Laurentian glacier basin around the Great Lakes in North America), in areas of heavy rainfall and repeated flooding (e.g., the Ganges valley, Bangladesh and the Amur valley), in geologically ancient soil subject to heavy rainfall (e.g., Pre-Cambrian exposed continental shield in central Africa); and in vast inland basins, as in Central Asia and the Great Basin in the western United States.

Recent evidence has indicated that iodine deficiency is found throughout the world. The deficiency and its consequences have re-occurred in all countries of the former Soviet area. The problem has emerged in countries previously thought safe, including many countries in Europe. It is widespread in Africa, in South and Central America, in the western Pacific areas of Indonesia and the Philippines, and in India, China and South-East Asia. Thus it is in fact a worldwide problem.

4. Monitoring and Measurement: Indices of Iodine Deficiency

Iodine intake and stores in humans are best measured by urine iodine output, measured as micrograms/liter, which over time closely reflects iodine intake. Recommended values of iodine intake by humans are 50 $\mu g\ day^{-1}$ from 0 to 12 months, 90 $\mu g\ day^{-1}$ from 1 to 6 years, 120 $\mu g\ day^{-1}$ from 7 to12 years, 150 $\mu g\ day^{-1}$ for adolescents and adults, and 200 $\mu g\ day^{-1}$ for pregnant women. Population median values above 100 $\mu g\ l^{-1}$ indicate iodine sufficiency; 50-100 $\mu g\ l^{-1}$ indicate mild iodine deficiency; 25-50 $\mu g\ L^{-1}$ moderate deficiency; and <25 $\mu g\ l^{-1}$ severe deficiency.

5. Methods of Iodine Supplementation

The standard method of providing iodine to populations living in iodine-deficient areas is through iodization of salt. Salt is the ideal vehicle for iodine distribution: it is virtually universally used, is inexpensive, and iodine can be added to it simply and inexpensively, without any adverse effect on the taste or utility of the salt. Iodine is usually added to salt for human consumption in the form of potassium iodide or potassium iodate by a simple mixing procedure at the plant for salt manufacture. The usual level of supplementation is 30 to 60 milligrams kg^{-1} (parts per million). During storage and transportation, particularly in wet conditions, iodine may be lost from the package, so assessment of the iodine content at the retail outlet and in the home is an important part of monitoring the adequacy of the supplementation program. Human intake of salt is about 10 grams day^{-1}; thus salt containing 20 ppm can provide about 200 μg of iodine day^{-1}. The most prevalent fortification method by industry (about 75-80% of all iodized salt) is wet spraying and mixing.

Salt for livestock is also commonly iodized. This is usually entirely separate from salt for human use, but may be shared in some instances. More often, the need for iodine for livestock is probably overlooked.

In some areas, and often in the most serious and critical areas of iodine deficiency, salt iodization is impractical for various reasons. In such areas, iodine supplementation can be attempted using oral capsules containing iodinated vegetable oil: one such capsule containing 400 mg of iodine can provide sufficient iodine supplementation for a person for 6 to 18 months. Alternatively, injection of a similar amount of iodinated oil intramuscularly provides an adequate iodine store for 2 to 4 years. Both these techniques are used in areas of severe iodine deficiency where iodized salt is not available. In practice, they have serious limitations in usefulness because of the need to organize regular administration, and the need for trained medical personnel in the case of intramuscular injections.

Other methods of iodine distribution include potassium iodide added to water supplies in public water systems and in village wells. Potassium iodide supplementation of bread and of brick tea (the latter in Tibet) has been tried. Overall, only salt iodization has been generally successful, and it is the method advocated universally by governments and international public health organizations.

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Biographical Sketch

Dr. DeLong was born in Lafayette, Indiana, in 1936. He attended DePauw University and Harvard Medical School in Boston, graduating in 1961. He trained in internal medicine, then did research in developmental neurobiology at the National Institutes of Health. He completed his residency in neurology and neuropathology at the Massachusetts General Hospital. He was appointed Chief of the Children's Neurology Unit at Massachusetts General Hospital and Harvard Medical School in 1969. Then began a life-long interest in human neurodevelopmental diseases, especially neuropsychiatric disorders, including investigations of childhood manic-depression, epilepsy, and infantile autism.

In 1980, he first encountered iodine deficiency disorder and protein-energy malnutrition as a consultant in Ecuador. His interest in mental retardation and cerebral palsy resulting from iodine deficiency led to further studies in Congo, Bhutan, and China. He was a founding member of the International Council for the Control of Iodine Deficiency Disorders and co-organizer of an NIH international conference on Iodine and the Brain in 1988. In 1989 he began a study, in collaboration with Dr. Cao Xue-yi and others, of iodine supplementation of pregnant women in Xinjiang Province, China. Seeking a method to counter iodine deficiency in the province, where iodized salt was not accepted by the populace, he conceived the idea of iodine supplementation via irrigation water. Studies of this method began in 1992. A major expansion of the program began in 1997, supported by Kiwanis International and UNICEF, as described in this article.

Dr. DeLong moved to Duke University in North Carolina in 1988, where he is Professor of Pediatric Neurology and continues his clinical research on autism and field research on iodine deficiency. He was a recipient of the Harvard Shriver Center Prize for Mental Retardation Research in 1995 and the E.H. Christopherson Lectureship and Award in 2002 for contributions to international child health. His wife Nancy has shared and assisted with all his fieldwork.