Iodine Status of Children from the Red Sea, and the Nile Valley Regions of the Sudan: *Implications for Health and Development*

By

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Author's Statement

I declare that the work presented in this thesis has not been previously submitted for another degree in this or any other educational institution. In addition, I confirm that all of the work, data analyses and interpretation were undertaken by me.

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ABBREVIATIONS

FAO	Food and Agriculture Organization
FND	Food and Nutrition Board
ICCIDD	International Council for Control of Iodine Deficiency Disorders
TSH	Thyroid Stimulating Hormone
UIC	Urinary Iodine Concentration
UNICEF	United Nations Children's Fund
WFP	World Food Program
WHO	World Health Organization

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ABSTRACT

Iodine deficiency leads to multitude disorders often refereed as "iodine deficiency disorders" that are preventable by supplementation. Iodine deficiency is the leading cause of brain damage and mental disability. Moreover, it is the most common cause of decreased fertility rate, miscarriages, stillbirths and foetal and infant mortality in the developing countries. Contrary to the widely held popular perception, iodine deficiency is not restricted to the developing countries. Investigations of urine of children and adults, and maternal milk reveal a high prevalence of iodine deficiency in many European countries as well as the United States. It is estimated; about 1.5 billion people in 118 countries are at risk of developing one or more of the disorders induced by iodine deficiency. Sudan is the largest country in Africa with diverse geographical and ecological regions. These diversities have had a major influence on nutrition and health of the various ethnic groups who live in the different regions. There is a scarcity of reliable published data on micronutrients, particularly iodine, status of Sudanese children. This thesis reports findings of investigations of iodine status of Sudanese school children who live in two contrasting regions of the country, Red Sea (Port Sudan) and Nile Valley (Jabal Awliya) states. The implications of the findings to health and development of the children, and nutrition and health policy have been assessed.

Two hundred two (n = 282) male and female children aged 6 to 12 years were enrolled from schools in the Port Sudan and Jabal Awliya using a multi-stage random sampling survey procedure. At recruitment, the children were assessed for urinary iodine and thyroid enlargement (visible goitre). Salt samples brought by the children from their home were tested for iodine content. In addition, information on the frequency of fish consumption by the children and family was obtained.

In Port Sudan, the median urinary concentration, prevalence of visible goitre, the percentage of children who consumed fish at least once a week and

iodine content of the collected salt samples were 555.2 µg /L, 17 %, 1.7 % and 150 - 360 mg/kg, respectively. The corresponding values in Jabal Awliya were 159.6 µg/L, 1.4 %, 77 % and 0 % (below the detection limit), respectively.

According to the World Health Organisation criteria of assessment of iodine level, the children from Jabal Awliya, in spite of consuming salt devoid of iodine, had optimal iodine status. This finding is borne out by the low prevalence of visible goitre, and optimal urinary iodine level. It appears; the Nile fish and the wheat, sorghum, beans and green vegetables, which grow in the alluvial soil of the river and are extensively consumed by families in the area, is rich in iodine.

Assuming children living in Port Sudan were consuming the recommended 5 g of salt per day, their intake of iodine was between 750 and 1800 µg/day. These high intakes were reflected in the elevated level of urinary iodine. The Recommended Dietary Allowance of iodine for adult men and women (non-pregnant and non-breast feeding), and children is 150 and 90 - 150 µg/day, respectively. Moreover, median urinary iodine concentrations of 100–200 µg/L indicate adequate iodine intake and optimal iodine nutrition. In contrast to the children from Jabal Awliya with adequate intake and status of iodine, those from Port Sudan are at higher risk of iodine-induced hypothyroidism resulting from consumption of excessively iodised salt.

The findings of this study clearly demonstrate a major problem with iodine nutrition and quality control and monitoring of salt iodisation programme in Sudan. There is a very urgent need for critical evaluation of the: (a) Health impact of excessive consumption of iodine in the whole country; (b) Guidelines and regulatory environment of iodisation of salt.

CHAPTER 1.

GENERAL INTRODUCTION

1.0. INTRODUCTION

In 1990, the World Health Assembly recognized that iodine deficiency is the world's greatest single cause of preventable mental retardation and established the goal of eliminating it as a public health problem by the year 2000 (WHO 1999).

Iodine (I_2), an essential nutrient, is a non-metallic element belonging to the halogen family, converted to iodide in the gut, efficiently absorbed in the digestive tract and carried into circulation by serum proteins. Most iodide is actively trapped by the thyroid and is present in the human body in minute amounts (15 - 20 mg in adults). The only confirmed function of iodine is as an essential substrate for the synthesis of thyroid hormones, tetraiodothyronine (thyroxin or T_4) and triiodothyronine (T_3) (Hetzel 1989). In target tissues, such as the liver and the brain, T3, the physiologically active thyroid hormone, binds to thyroid receptors in the nuclei of cells and regulate gene expression. T4, the most abundant circulating thyroid hormone, is converted to T3 by enzymes, known as deiodinases in target tissues. In this manner thyroid hormones regulate a number of physiologic processes, including growth, development, metabolism and reproductive function.

Iodine (as iodide) is widely but unevenly distributed in the earth's environment. Most iodide is found in the oceans, about 50 µg/L. Iodide ions in seawater oxidise to form elemental iodine, which is volatile and evaporates into the atmosphere and returns to the soil by rain, completing the cycle. However, the cycle of iodine in many regions is slow and incomplete, and soils and groundwater become deficient in iodine. Crops grown in these soils will be low in iodine concentration and man and animals consuming food grown in these soils become deficient in iodine.

In plants grown in deficient soils, the iodine concentration might be as low as 10 µg/kg of dry weight, compared with about 1 mg/kg in plants from iodine-sufficient soils. Iodine-deficient soils are common in inland regions, mountainous areas, and places with frequent flooding but it can also occur in coastal soils. Iodine deficiency in populations residing in these areas will persist until iodine enters the food chain through addition of iodine to foods, i.e.

iodisation of salt or dietary diversification introduces foods produced in iodine-sufficient regions.

The recommended intake of iodine is 150 µg per day and the thyroid has to trap about 60 µg per day to maintain an adequate pool (Fisher 1985). The excretion of ingested dietary iodine in the faeces has been reported to be 30 % (Follis 1964). However, some of the nutrients such as isoflavones and thiocyanates have been shown to interfere with the utilization of iodine. Some of the examples are isoflavones and thiocyanates; isoflavones are commonly found in soy foods and thiocyanates are converted from glucosinolates rich in cruciferous vegetables such as broccoli.

150 µg per day of iodine in a supplement is sufficient to prevent clinical manifestation of iodine deficiency disorders if iodine would become absent from the diet (Dunn 1993, Stanbury 1998). Goitre becomes almost universal in a population with an iodine intake less than 10 µg per day (Fisher 1985). Collectively, health problems arising from a lack of iodine are known as iodine deficiency disorders.

Both inadequate and high intakes of iodine are associated with thyroid disease and associated abnormalities. Consumption of foods deficient in iodine induces hypothyroidism. Conversely, excessive intake of the fortified food with iodine nutrient precipitates hyperthyroidism, i.e. consumption of iodised salt (more than 40 mg/kg) (Andersen 2008). Administration of large amounts of iodine through dietary excess such as iodised salt, kelp, etc. cause hypo or hyperthyroidism, especially in individuals that already have thyroid problems, such as nodules, hyperthyroidism and autoimmune thyroid disease. In addition, individuals who move from an iodine-deficient region to a region with adequate iodine intake may also develop thyroid problems (iodine-induced hyperthyroidism) since their thyroids have become so very efficient at taking up and using small amounts of iodine (Delong 1994). Two billion individuals worldwide have insufficient iodine intake, with people living in the Middle East and North Africa and sub–Saharan Africa are being particularly affected (WHO 2007).

Determination of iodine deficiency disorders prevalence includes methods of assessment such as urinary iodine concentration, total goitre rate, iodine content of salt and newborn thyroid-stimulating hormone, and blood thyroglobulin (Zimmermann 2009). In nearly all countries, the best strategy to control iodine deficiency is iodisation of salt, which is one of the most cost effective ways to contribute to economic and social development. Iodine supplement can be given to susceptible groups when iodised salt is not available (Zimmermann 2009).

1.1. NOMENCLATURE AND BIOCHEMISTRY OF IODINE

Iodine stems from the Greek: (*iodes* "violet"). It is a chemical element that has the symbol (I) and atomic number 53. Naturally occurring iodine is a single isotope with 74 neutrons. Bernard Courtois discovered iodine in 1811 (Cotton & Wilkinson 1974). Chemically, iodine is the least reactive of the halogens and the most electropositive halogen after astatine. However, the element does not occur in the free form in nature. As with all other halogens (members of Group VII in the Periodic Table), iodine forms diatomic-molecules (I_2) when it is freed from its compounds (Merck Index 9th ed 1983).

Elemental iodine is poorly soluble in water, with 1 g dissolving in 3450 ml at 20 °C and 1,280 ml at 50 °C. By contrast with chlorine, the formation of the hypohalite ion (IO^-) in neutral aqueous solutions of iodine is negligible (Advanced Inorganic Chemistry 2nd ed).

$$I_2 + H_2O \rightleftharpoons H^+ + I^- + HIO \quad (K = 2.0\times10^{-13})$$

Solubility in water is greatly improved if the solution contains dissolved iodides such as hydroiodic acid, potassium iodide, or sodium iodide; this extra solubility results from the high solubility of the I_3^- ion. Dissolved bromides also improve water solubility of iodine. Iodine is soluble in a number of organic solvents, including ethanol (20.5 g/100 ml at 15 °C, 21.43 g/100 ml at 25 °C), diethyl ether (20.6 g/100 ml at 17 °C, 25.20 g/100 ml at 25 °C), chloroform, acetic acid, glycerol, benzene (14.09 g/100 ml at 25 °C), carbon tetrachloride (2.603 g/100 ml at 35 °C), and carbon disulfide (16.47 g/100 ml at 25 °C).

Aqueous and ethanol solutions are brown. Solutions in chloroform, carbon tetrachloride, and carbon disulfide are violet.

Elemental iodine can be prepared by oxidizing iodides with chlorine:

$$2I^- + Cl_2 \rightarrow I_2 + 2Cl^-$$

or with manganese dioxide in acid solution:

$$2I^- + 4H^+ + MnO_2 \rightarrow I_2 + 2H_2O + Mn^{2+}$$

Iodine is reduced to hydroiodic acid by hydrogen sulphide:

$$I_2 + H_2S \rightarrow 2HI + S\downarrow$$

or by hydrazine:

$$2I_2 + N_2H_4 \rightarrow 4HI + N_2$$

Iodine is oxidized to iodate by nitric acid:

$$I_2 + 10HNO_3 \rightarrow 2HIO_3 + 10NO_2 + 4H_2O$$

or by chlorates:

$$I_2 + 2ClO_3^- \rightarrow 2IO_3^- + Cl_2$$

Iodine is converted in a two stage reaction to iodide and iodate in solutions of alkali hydroxides (such as sodium hydroxide).

1.2. IODINE AND ITS DISTRIBUTION IN THE ENVIRONMENT

Distribution of iodine was studied in soils, soil micro - organisms, water and dominating plant species collected in flood plains and watershed landscapes formed on different geochemical types of sedimentary rocks, (Whitehead 1984). Iodine in a significant amount is only found in a few foods, most iodine resides in the ocean where the iodine content is 30 – 60 µg/L (Vought 1963). The iodine content of food depends on the iodine content of the soil in which it is grown. The iodine present in the upper crust of earth is leached by glaciations and repeated flooding and carried to the sea. Seawater is, therefore, a rich source of iodine (Koutras 1985). The seaweed located near coral reefs has an inherent biologic capacity to concentrate iodine from the sea. The reef fish, which thrive on seaweed, are also rich in iodine. Thus, a population consuming seaweed and reef fish has a high intake of iodine, as is the case in Japan (WHO 1996).

The iodine content in the soil depends on a number of factors. In general, the older an exposed soil surface, the more likely it is to be leached of iodine. Mountainous areas are most severe iodine deficient areas. Although the element is actually quite rare, kelp and certain plants and algae have some ability to concentrate iodine, which helps introduce the element into the food chain (Burgi 1990). Volatilization of iodine from the oceans, possibly as elemental iodine or as an organically bound species, is the main source of the element in the environment. The distribution of iodine in the secondary environment is, therefore, largely controlled by proximity to the oceans, with rainwater and surface run-off relatively enriched in iodine in near-coastal regions. Soil iodine content is also strongly influenced with coastal soils being much enriched and central continental soils being depleted. While iodine input is a major controlling influence on its geographical distribution in soils, the soil's ability to retain iodine is also an important factor. Organic matter together with iron and aluminium oxides and clays are the important sinks of soil iodine (Fuge Geological Society 1996). Iodine occurs in the soil and the sea as iodide. Iodide ions are oxidized by sunlight to elemental iodine, which is volatile, thus iodine escapes from the surface of the sea. Cooking, especially boiling reduces the iodine content (Laurberg 1994). Iodine is found in the mineral caliches in Chile, between the Andes and the sea.

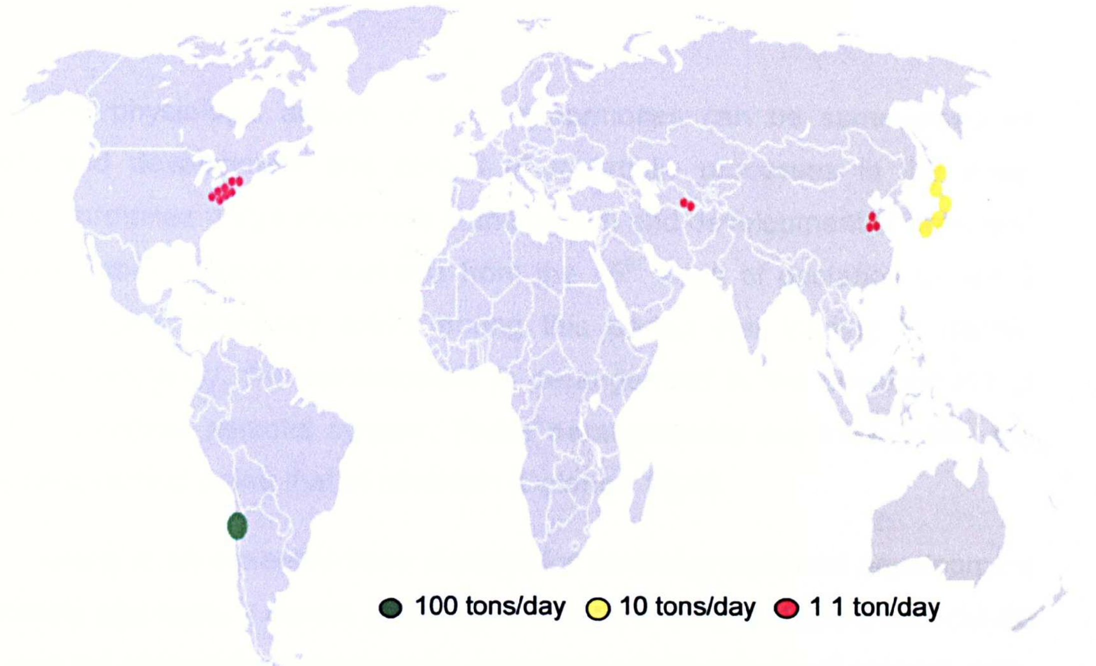

Figure 1.1. Iodine output in 2005 shown as a percentage of the top producers (Chile – 15,346 ton per year) {Source: Levin 1991}

The map in the Figure 1.1 shows that in 2005, Chile was the top producer of iodine with almost two-thirds world share followed by Japan and the USA. Iodine is also found in some seaweed as well as extracted from seawater. However, extracting iodine from caliches is the only economical way to extract the substance (Levin 1991).

1.3. BIOLOGICAL FUNCTIONS

All biologic actions of iodide are attributed to the thyroid hormones. The major thyroid hormone secreted by the thyroid gland is T_4 (tetra-iodo-thyronine). T_4 in circulation is taken up by the cells and is de-iodinated by the enzyme 5' prime-mono-de iodinase in the cytoplasm to convert it into tri-iodo-thyronine (T_3), the active form of thyroid hormone. T_3 traverses to the nucleus and binds to the nuclear receptor. All the biologic actions of T_3 are mediated through the binding to the nuclear receptor, which controls the transcription of a particular gene to bring about the synthesis of a specific protein (Hetzel1983).

The physiologic actions of thyroid hormones can be summarised as growth and development and control of metabolic processes in the body. Thyroid hormones play a major role in the growth and development of brain and central nervous systems in humans from the 15th week of gestation to age 3 years. If iodine deficiency exists during this period that leading to thyroid hormone deficiency, the consequence is derangement in the development of brain and central nervous system. These derangements are irreversible, the most serious form being that of cretinism (Delange 1999).

Iodine is an essential trace element for normal growth and development in animals and man. It occurs in the human body in only small amounts (15-20 mg) and the essential requirement for normal growth is only small amount (100-150 µg) per day (0.1 - 0.15 mg).Therefore, iodine is referred to as trace element (Merck 1984). The healthy human adult body contains 15 to 20 mg of iodine of which 70 to 80 % is in the thyroid gland (Benmiloud 1994). At present, the only physiologic role known for iodine in the human body is in the synthesis of thyroid hormones by the thyroid gland (Laurberg 2000). The special biological importance of iodine arises from the fact that it is a constituent of the thyroid hormones, thyroxine3, 5, 3'5'–tetraiodothyronine (T_4) and 3,5,3' –triiodothyronine (T_3) (Hetzel 1985). Thyroid hormones play a very basic role in biology, acting on gene transcription to regulate the basal metabolic rate. The total deficiency of thyroid hormones can reduce basal metabolic rate up to 50%, while in excessive production of thyroid hormones the basal metabolic rate can be increased by 100 % (Bayliss 1991).

The iodide is used by the thyroid gland for synthesis of the thyroid hormones, and the kidney excretes iodine with urine. The excretion of iodine in the urine is a good measure of iodine intake. In a normal population with no evidence of clinical iodine deficiency either in the form of endemic goitre or endemic cretinism, urinary iodine excretion reflects the average daily iodine requirement (Delange 1994).

The regulation of the thyroid hormones is a complex process involving not only the thyroid, but also the pituitary and the peripheral tissues (Benmiloud 1994). The other physiologic role of the thyroid hormone is to control several metabolic processes in the body. These include carbohydrate; fat, protein, vitamin and mineral metabolism. For example, the thyroid hormone increases energy production, increases lipolysis and regulates neo-glycogenesis and glycolysis (Merimee 1979).

1.4. RECOMMENDED IODINE INTAKE

Iodine is ingested in a variety of chemical forms in food. Most ingested iodine is reduced in the gut and absorbed almost completely. Some iodine containing compounds are absorbed intact. The thyroid selectively concentrates iodide in the amounts required for adequate thyroid hormone synthesis (Institute of Medicine 2001). The official dietary recommendation for iodine for adult varies; 140 µg/day in England (Wilson 1967), 180–200 µg/day in Germany (Knudsen 1999), 150 µg /day in Denmark (Rasmussen 2001), 150 µg/day in the USA, and 160 µg/day in Canada (Bartels and Böhmer 1971).

For adults in England and in the USA, the recommendations are based on a minimum daily intake of about 70 µg/day, but the Food and Nutrition Board, concluded that the adult iodine intake in the USA is usually 240 – 300 µg/day from foods (Institute of Medicine 2001). This confirms that iodine intake in the USA is within the international recommended norms (WHO 2007). Canada has based its recommendation on the amount of iodine required to maintain a normal plasma concentration of 0.15 µg/L with a high renal clearance rate of 55 ml/min. Studies have found that iodine intakes ranging from 44 to 162 µg/day are sufficient to maintain a positive balance. The recommended intake was therefore set at 160 µg/day (Bartels and Böhmer 1971).

The World Health Organization (WHO) recommends that the daily intake of iodine should be 90 µg for preschool children (0 to 59 months); 120 µg for schoolchildren (6 to 12 years); 150 µg for adolescents (above 12 years) and adults; 250 µg for pregnant and lactating women (WHO 2007).

1.5. IODINE REQUIREMENT DURING PREGNANCY

The iodine requirement during pregnancy is increased to provide for the needs of the foetus and to compensate for the increased loss of iodine in the urine resulting from an increased renal clearance of iodine during pregnancy (Wayne 1964). These requirements have been derived from studies of thyroid function during pregnancy and in the neonate under conditions of moderate iodine deficiency. For example, in Belgium where the iodine intake is estimated to be 50 - 70 µg/day (Bourdoux 1986), thyroid function during pregnancy is characterised by a progressive decrease of the serum concentrations of thyroid hormones and an increase in serum thyroid stimulating hormone (TSH) and thyroglobulin.

Thyroid volume progressively increases and is above the upper limit of normal in 10 % of the women by the end of pregnancy. Serum TSH and thyroglobulin are still higher in the neonates than in the mothers (Delange1997). These abnormalities are prevented only when the mother receives a daily iodide supplementation of 161 µg/day during pregnancy (derived from 131 µg potassium iodide and 100 µg T_4 given daily) (Moulopoulos 1988).

The recommended dietary intake of iodine during pregnancy is higher than the value of 150 µg/day recommended for non-pregnant adults and adolescents (Institute of Medicine 2001). The WHO and United Nations Children's Fund (UNICEF) and the International council For Control of Iodine Deficiency Disorders (ICCIDD) technical consultation proposed to increase the current Food and Agriculture Organization (FAO) and the WHO recommended nutrient Intake for iodine during pregnancy from 200 µg/day to 250 µg/day (Table 1.1). A daily intake greater than this is not necessary and preferably should not exceed 500 µg/day, as higher intake is usually associated impaired thyroid function (IDD Newsletter 2005).

Table 1.1. Recommended dosage of daily and annual iodine supplementation

Population group	Daily dosage of iodine supplement µg/day	Single annual dose of iodised oil supplement µg/y
Pregnant women	250	400
Lactating women	250	400
Women of reproductive age (15 – 49 year)	150	400
Children < 2 years*	90	200

{Source: Indicators for assessing Iodine deficiency Disorders and their control through salt iodization, WHO 2007}

**These figures for iodine supplements are given in situations where complementary food fortified with iodine is not available, in which case iodine supplementation is required for children of 7 – 24 months of age.*

1.6. IODINE REQUIREMENTS DURING LACTATION AND INFANCY

The daily intake of iodine recommended by the National Research Council of the US National Academy of Sciences in 1989 was 40 µg/day for young infants (0 - 6 months, 50 µg/day for older infants 6 - 12 months) (Delange 1988). The recommendation of 40 µg /day for infants aged 0 – 6 months (or 8 µg/kg/day, 7 µg /100 kcal, or 50 µg/L milk) is probably based on the observation reported in the late 1960s that the iodine content of human milk was approximately 50 µg/L and the assumption that nutrition of the human milk fed infant growing at a satisfactory rate represents an adequate level of nutrient intake (Delange 1988).

The recent data indicate that the iodine content of human milk varies markedly as a function of the iodine intake of the population (Semba and Delange 2001). On this basis, an average human milk intake of 750 ml/day would give an intake of iodine of about 60 mg/day in Europe and 120 mg/day in the United States. The upper United States value (490 µg/L) would provide 368 µg/day or 68 µg/kg/day for an infant weighing 5 kg. Positive iodine balance in the young infant, which is required for increasing the iodine stores of the thyroid, is achieved only when the iodine intake is at least 15 mg/kg/day in term infants and 30mg/kg/day in preterm infants (Delange 1993). The iodine requirement of preterm infants is twice that of term infants because of a much lower retention of iodine by preterm infants (Delange 1993). Based on the assumption of an average body weight of 6 kg for a child of 6 months, 15 mg/kg/day corresponds approximately to an iodine intake and requirement of 90 µg /day. This value is two-fold higher than the present United States recommendations. On the basis of these considerations, the WHO in 2001 updated its 1996 recommendations (WHO 1996) and proposed, together with UNICEF and ICCIDD that daily iodine intake should be 90 mg from birth onwards (WHO 2001). To reach this objective and based on an intake of milk of about 150 ml/kg/day, it was further proposed that the iodine content of formula milk be increased from 50 µg/L (the former recommendation) to 100 µg/L for term infants and to 200 µg/L for preterm infants.

1.7. IODINE REQUIREMENT IN ADOLESCENTS AND ADULTS

The UNICEF, ICCIDD and WHO (WHO 2007), and ICCIDD (IDD Newsletter 2007) recommended that the daily intake of iodine for adolescents is 150 µg. A requirement for iodine of 150 µg/day for adolescents and adults is justified by the fact that it corresponds to the daily urinary excretion of iodine and to the iodine content of food in non-endemic areas, i.e. in areas where iodine intake is adequate (Delange 1994). It also provides the iodine intake necessary to maintain the plasma iodide level above the critical limit of 0.10 mg/dl, which is the average level likely to be associated with the onset of goiter (Wayne 1964). Moreover, this level of iodine intake is required to maintain the iodine stores of the thyroid above the critical threshold of 10 mg, below which an insufficient level of iodination of thyroglobulin leads to disorders in thyroid hormone synthesis (Delange 1994).

1.8. DIETARY SOURCES AND GOITROGENS

Salt-water fish and seaweed are good sources of iodine, although the content in fish varies a lot from species to species (Table 1.2) and also within species (Møller and Saxholt 1996). Iodine is found in the soil and in the sea, hence dietary iodine availability is determined primarily by soil composition and amount of seafood consumed (Hetzel 1989). The oral intake also includes iodine from water and beverages, however food provides by far the major contributor to the total iodine exposure (Park 1981). Presently, the main additional iodine source beside the food is iodised kitchen salt (Burgi 1998).

Classification of fish populations according to iodine concentration is difficult as there is large variation between fishes of the same species (Karl 2001). Added salt used for cheese manufacturing is generally iodised and the salting will affect the concentration and the distribution of iodine within the cheese, e.g. soaking the pressed cheese in brine (Hoffmann 1997).

Table 1.2. Iodine content in various raw fish

Fish	Mean (µg/100g)	Variation (µg/100g)	No. of samples
Herring	30	8 - 116	36
Codfish	188	12 - 652	70
Tuna fish (canned)	7	2 - 17	15
Mackerel	90	17 - 240	24
Shrimp	14	5 - 18	7
Seaweed (kelp, dried)	36,000	-	-

{Source: Møller and Saxholt 1996}

In some countries, iodised salt is also used during manufacture of processed foods, e.g. bread in the Netherlands, a major source of dietary iodine in the Dutch diet (Brussard 1997). Iodised salt was first introduced in Europe in 1922 and is available nationwide in most countries today, however, the nutritional impact of iodised table salt has received renewed attention recently (Delange 1996). New data based on urinary excretion, which indicate a decline in iodine intake, have been reported from schoolchildren in Switzerland (Zimmermann 1998) and blood donors in New Zealand (Thomson 1997). Although U.S. dietary iodine is generally adequate, some groups, especially women of childbearing age are at risk of mild iodine deficiency (Joseph 1998). Data on iodine contents of food items are relatively scarce, except for milk and fish (Julsham 2001).

1.9. IODINE DEFICIENCY DISORDERS

Iodine deficiency is the cause of an ancient scourge of mankind. This scourge includes goiter and brain damage at all ages beginning with the foetus during pregnancy. Exclusive studies throughout the world over the last 20 years have revealed that 130 countries are affected by iodine deficiency, with a total population in excess of two billion at risk of the occurrence of varying degrees of brain damage (WHO/UNICEF/ICCIDD 1993). The term iodine deficiency disorders were coined in 1983 to underscore the wide range of serious adverse effects of iodine deficiency (Hetzel 1983). Iodine deficiency is a disease of the soil where the environmental deficiency results in the manifestation of the disease state in humans, perched on the top-most level of the food chain (Hetzel 1993).

Iodine deficiency disorders are recognized as a major global health problem, in particular in developing countries but also in Europe (Delange 1996). In a severely iodine deficient area, cretinism with a prevalence of 1 - 10 % is only the visible portion of an iceberg which includes an invisible but very substantial volume of effects due to lesser degrees of brain damage and cerebral hypothyroidism (Stanbury 1994). The oldest reports about iodine deficiency and more specifically goiter come from China (Hetzel 1989). In the middle ages, iodine deficiency was very common in Europe. For instance, cretins were a common site in the Alps, Switzerland. In the Middle East, goiter was common; in fact, some speculates that Cleopatra had a goiter (Delange 1986).

1.10. CLINICAL AND SUBCLINICAL MANIFESTATIONS OF IODINE DEFICIENCY

Iodine deficiency causes hypothyroidism, resulting in thyroid enlargement, mental retardation, increased neonatal and infant mortality, retardation of growth and development of the central nervous system in children (cretinism), reproductive failure, and an increase of fluid in the tissues–myxoedema (Delong 1994). An iodine-deficient diet causes a wide spectrum of illnesses (Table 1.3), including goitre and mental retardation. In addition to goitre, iodine deficiency disorders include a spectrum of conditions that vary in severity. The healthy adult human body contains 15 – 20 mg of iodine of which about 70 – 80 % is in the thyroid gland. The thyroid weighs 15 - 25 g, the pool of iodine is concentrated mainly in the thyroid (Hetzel 1983). However, in response to prolonged iodine deficiency, the thyroid gland can increase about five-fold to the size of football, a condition recognized as goiter (Kondo 2006).

Figure 1.2. An older boy with cretinism

Figure 1.3. Children with cretinism

Table 1.3. Spectrum of iodine deficiency disorders

Foetus	Abortion, stillbirths, congenital anomalies, increased prenatal and infant mortality, neurologic cretinism (mental deficiency, deaf autism, spastic dysplasia, and squint), hypothyroid cretinism, psychomotor defects.
Neonate	Neonate goitre, Neonatal hypothyroidism
Child and Adolescent	Goitre, juvenile hypothyroidism, impaired mental function and retarded physical development, overt or sub clinical hypothyroidism.
Adult	Goitre and its complications, Hypothyroidism, Endemic mental retardation, Decreased fertility rate, Impaired mental function, and Iodine induced hyperthyroidism.
All Ages	Goitre, hyperthyroidism, impaired mental function, increased susceptibility to nuclear radiation.

{Source: Hetzel 1993}

1.11. PREVALENCE OF IODINE DEFICIENCY DISORDERS

Iodine deficiency is common, especially in Asia and Africa, but also in large parts of Eastern Europe. Only a small number of countries currently have sustainable iodine sufficiency and about a third of the world's population lives in areas with some iodine deficiency. Inland areas, especially mountainous areas like the Alps, Himalayas and the Andes and the Nuba Mountain in Sudan are particularly iodine deficient (Dunn 1998). Iodine deficiency disorders are a global health problem with nearly two billion people at risk (FAO/WHO/IAEA 1996). In countries such as China, the incidence of iodine deficiency disorders in children and pregnant women in areas of iodine deficiency is estimated to be up to 50 % (Angermayr and Clar 2005). In certain Asian, African and Latin American countries iodine deficiency disorders affect more than 200 million people (Table 1.4), more than 173 million individuals in Eastern Mediterranean are at risk of iodine deficiency disorders (WHO 1993). It is observed that the prevalence and those at risk of iodine deficiency disorders is 42 - 32 %, in Middle East and Africa consecutively.

Table 1.4. Total number of people and percent of regional population living in areas at risk of or affected by iodine deficiency disorders *

Regions	Population	At risk of IDD		Affected by goitre		Affected by impaired Mental development	
	(Millions)	(Millions)	(%)	(Millions)	(%)	(Millions)	(%)
Africa	550	181	32.8	86	15.6	1.1	0.2
Americas	727	168	23.1	63	8.7	0.6	0.9
Middle East	406	173	42.6	93	22.9	0.9	2.3
Europe	847	141	16.7	97	11.4	0.9	1.1
South-East Asia	1355	486	35.9	176	13.0	3.2	1.3
Western Pacific	1553	423	27.2	142	9.0	4.5	2.9
Total	5438	1572	28.9	655	12.0	11.2	2.0

{Source: WHO/UNICEF/ICCIDD 1993}

1.12. DIAGNOSIS AND TREATMENT

The assessment of iodine deficiency disorders procedures are given by the WHO in collaboration with the UNICEF and ICCIDD (WHO 2001 & 2007).

One variable often measured is thyroid size. However, the determination of thyroid size is not feasible in neonates and it may be of limited use in school children of 8 to 12 years, a group often studied, as the highest prevalence of goitre occurs during puberty and childbearing age (Dunn 1996).

The two most common methods of measuring thyroid size are by palpation or ultrasonography (WHO 2007). While many studies assess goitre by palpation, the WHO suggests that this is not a very useful technique for determining the impact of iodisation programmes, where thyroid volumes may decrease over time, making them more difficult to assess (Delong 1994). The technique and classification of measurement of goitre by palpation are specified by WHO (WHO 2007). Ultrasonography is the method of choice for assessing the impact of iodisation programmes on thyroid size. An application of the technique is becoming feasible even in remote areas of the world ("*Thyromobil Project*"). It should be noted however, that in adults with longstanding goitres, correction of iodine deficiency may have less of an impact on thyroid size than in children (Dunn 1996).

Measurement of TSH levels, which are expected to be elevated in iodine deficiency, is not a reliable indicator in school children and adults as differences from normal levels are small and there is a large overlap between values in people who are iodine sufficient and those who are iodine deficient. However, TSH levels are a good indicator of iodine deficiency in neonates. Increased thyroglobulin levels are a good indicator of thyroid hyperplasia resulting from iodine deficiency. Thyroglobulin levels reflect iodine nutrition over months and years, whereas urinary iodine levels measure the more immediate effects of increased iodine intake on iodine status. However, measurement of thyroid hormones (T_3 and T_4) is not recommended (WHO 1993).

Large programmes for the prevention of iodine deficiency – or more specifically endemic goitre - using iodised salt were already initiated in Switzerland and in the USA in the 1920s, where large surveys of goitre incidence before and after the intervention showed the use of iodised salt to be an effective preventative intervention (WHO 19992005).

At the fourth meeting of World Health Assembly meeting in 1973, diagnostic criteria, measures of intervention, and directions of research were suggested. At the fifth meeting in 1983, these diagnostic criteria were revised. In 1986, the ICCIDD was established in Kathmandu, Nepal. Based on the proposal of the ICCIDD, the 39th World Health Congress in 1986 declared that iodine deficiency disorders should be controlled within the following ten years (Hetzel1993). However, iodine deficiency disorders had not been eliminated and 36 affected countries had not introduced salt iodisation programmes by 2001 (Delange 2001). The UN has now extended the deadline for (virtual) elimination of iodine deficiency worldwide to 2015 (UNICEF 2006).

Iodised salt, iodised bread, iodised water; iodine tablets and iodised oil (given orally or by injection) are commonly used for preventing iodine deficiency disorders. Iodised salt is considered the most appropriate means of iodine supplementation. The current recommended level of salt iodisation is 20 - 40 mg iodine per kg of salt. However there have been problems with implementing salt iodisation in countries with numerous scattered salt deposits and complex distribution systems, so alternatives are sometimes required (Dunn 1998). Also, salt consumption in adults has been linked to hypertension, and as hypertension and cardiovascular disease are growing healthcare problems, a reduction of salt intake is recommended, which may at the same time reduce iodine intake to inadequate levels (Cann 2002).

Other longer term solutions include iodisation of water supplies. Iodine supplements in the form of tablets or injections can be dosed more accurately than food supplements, but some of these interventions require personal contact with the population to be treated (i.e. a large administrative effort) and methods providing intermittent doses of iodine provide uneven levels of iodine during the months between administration (Dunn 1996).

The response to supplemental iodine may be reduced by other factors in the environment, such as consumption of specific goiterogenic foods. For example, cassava (also called *manioc* in the Africana local language) and deficiency of other trace elements in the diet, such as selenium (Yang 1997, Köhrle 1999) or iron (Zimmermann 2000).

1.13. ADVERSE EFFECT OF HIGH IODINE INTAKE

Iodine deficiency disorders affect human health throughout the life cycle from foetal to the adult life. A severe iodine deficiency can cause hypothyroidism and even developmental brain disorders and severe goitre. Less severe iodine deficiency is linked to hypothyroidism, thyroid enlargement (goitre) and hyperthyroidism. At the other end of the spectrum, excessive iodine intake - both severe and moderate is also associated with hypothyroidism and gaiter (Zimmermann, 2005). The spectrum of iodine deficiency disorders includes abortion, congenital anomalies, mental deficiency, hypo and hyperthyroidism, mental retardation, goitre and many other problems.

Previous studies have shown that iodine-induced hyperthyroidism can occur following the introduction of iodised salt and suggest that the risk of this adverse effect is related to the level of intake, although it is limited to a relatively short period of time after introduction (Gomo 1999). A research team from China Medical University in Shenyang looked at the thyroid effects of supplement to three separate groups: people who were mildly iodine-deficient, those with adequate iodine intake, and those with excessive iodine intake. They found that iodine supplement to people who had adequate or excessive iodine intake lead to hypothyroidism autoimmune thyroiditis (Teng 2006).

Excessive iodine can trigger autoimmune thyroid disease and hypothyroidism. According to animal studies, high iodine intake can initiate and worsen infiltration of the thyroid by lymphocytes. Lymphocytes are white blood cells that accumulate due to injury or irritation. In addition, large amounts of iodine block the thyroid's ability to make hormone (Teng 2006).

When there is excessive iodine intake in the human body the thyroid gland starts to overproduce thyroid hormone and when this happens the bodies autoimmune system starts to attack and shut down the thyroid gland to a point where it actually causes hypothyroidism (Utiger 2006). On the other hand, if a person is pre-disposed to either Grave's disease of nodular goitre then too much iodine cause hyperthyroidism. A healthy thyroid gland handles excessive iodine intake by controlling how much iodine it takes in and last. In the case of condition Hashimoto's, too much iodine intake will cause thyroid gland to slow down thyroid hormone production even more than it already is (Higdon 2003).

The WHO, UNICEF and ICCIDD regularly review the recommended iodine content of salt. The latest guideline (WHO 2007) recommended the fortification level of salt iodisation at production sites between 20 and 40 mg of iodine per kg of salt. The guideline also clearly described the monitoring and evaluation procedures. A study was conducted to determine if chronic high iodine intakes are associated with increased thyroid size in school-age children. Although the findings support the contention that moderately high dietary intakes of iodine in the range of 300 - 500 µg/d are well tolerated by healthy children (Institute of Medicine 2001).

1.14. GLOBAL GOAL OF ELIMINATION OF IODINE DEFICIENCY DISORDERS

Between 1994 and 2006, the number of countries that carried out a urinary iodine national survey increased to 94, and survey data on iodine deficiency now covers 91.1 % of the world population. However, there is still no data for 63 countries, which together represent 8.9 % of the world population. Out of the 130 countries with estimates based on surveys at both the national and sub-national level, there are only 47 countries where iodine deficiency disorders still remains as a public health problem, compared to 54 in 2004 and 126 in 1993. Iodine intake (reflected by the median urinary iodine concentration) in the other 83 countries is as follows: "adequate" (UIC between 100 ug/L and 200 ug/L or "above recommended nutrient intakes" (UIC between 200 ug/L and 300 ug/L) in 76 countries; and "excessive" (UIC above 300 ug/L) in seven countries. About 31 % (1,900 million) of the world population is estimated to have insufficient iodine intakes, with the most affected WHO regions being South East Asia and Europe (Table 1.5). It is currently estimated that 70 % of households throughout the world have access to and use iodised salt (UNICEF 2007).

Health planners and the international agencies are increasingly recognizing that the elimination of iodine deficiency is an attainable goal with important benefits. The World Summit for Children held in New York in September 1990, called for the virtual elimination of iodine deficiency disorders by the year 2000. The main strategy to achieve the goal was agreed to be the universal salt iodisation (UNICEF/WHO 1994).

Table 1.5. Proportion of population (all age groups) with insufficient iodine intake*.

WHO Regions	Inadequate Iodine Nutrition		% Household with access to iodised salt [c]
	Proportion (%) [a]	Total number (million) [b]	
Africa	41.5	312.9	66.6
Americas	11.0	98.6	86.8
South East Asia	30.0	503.6	61.0
Europe	52.0	459.7	49.2
Eastern Mediterranean	47.2	259.3	47.3
Western Pacific	21.2	374.7	89.5
TOTAL	30.6	1 900.9	70

*The source of this information is based on:

a. WHO global database on IDD (http://www.who.int/vmnis)
b. Surveys from 130 countries made available to WHO and carried out between January 1994 and December 2006
c. Country data on proportion of households using iodised salt based on UNICEF global database (http://www.childinfo.org) and the State of the World's Children (SOWC) nutrition table, 2005.

There was an urgent need to bridge a great gap between research on the subject of iodine deficiency and brain damage and its application in public health programme. This global momentum around iodine deficiency disorders was followed in Montreal (1991) by another historic conference convened by the WHO and UNICEF on "*Ending Hidden Hunger*" (UNICEF/WHO/ICCIDD 1991). In 2002, the special sessions on children of the United Nations General Assembly adopted a comprehensive set of goals, the World Fit For Children Goals that focused on reducing malnutrition in children under 5 years of age by at least one-third through supportive strategies that include " ... *achieving the sustainable elimination of iodine deficiency disorders by 2005 and accelerate progress towards the reduction of other micronutrient deficiencies, through* *dietary diversification, food fortification, and supplementation* ...." (United Nations 2002). In the early 1990s, it was estimated that approximately 655 million people or 12 % of the world's population were affected by clinical disorders associated with iodine deficiency due to a lack of iodine in the diet such as goitre (WHO 1993). Finally, the economic impact of micronutrient deficiencies and more specifically of iodine deficiency on poorer countries' development and economic wellbeing became more established (World Bank 1994).

1.15. IODINE DEFICIENCY DISORDERS IN SUDAN

Sudan is the largest country in Africa, extending to 2.5 million square km, with a population of 40,187,486. Because it is so big, it has a range of climatic areas from tropical regions in the south, through featureless plains with varying rainy seasons, to the desert in the north. There are also mountain areas in the south and west. Population information for Sudan has been limited but the main features are high birth rate, high infant mortality and a high premature death rate, though this is beginning to decline (Federal Ministry of Health Sudan 2000). A large percentage of Sudan's people are under fifteen years old and the country is expected to have rapid population growth with total fertility rate of 4.85 children born/woman, and life expectancy of 58.5 years (total population). Major diseases with high degree of risk are mainly food and waterborne diseases: malnutrition and micronutrients disorders constitute serious public health issue, with high mortality and morbidity rate. Although urbanization rate is high, the country is still predominantly rural (Federal Ministry of Health Sudan 1997, UNICEF 2002). More than 90 % of the population suffers from poverty and food insecurity. At the beginning of 2004, World Food Program (WFP) and FAO estimated that 3.6 million inhabitants were in need of food assistance, with internally displaced people, refugees and returnees particularly exposed to food insecurity, health problems and insecurity (FAO 2005).

Sudan like many other developing countries has a long history of iodine deficiency. Iodine deficiency disorders constitute a public health problem in

Sudan. It affects children and women throughout life. More than 2 out of 10 school age children have goitre (Federal Ministry of Health Sudan 2000).

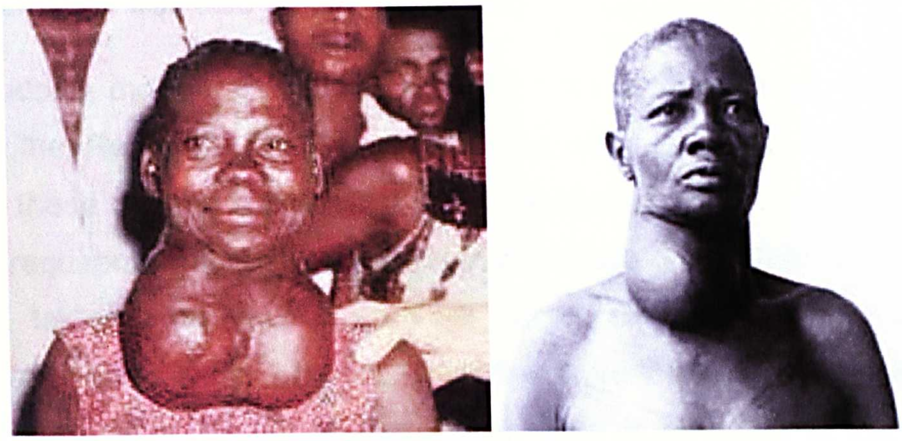

Figure 1.4. Women with severe goitre

Endemic goitre in Sudan was first reported in 1952 in a small area inhibited by A'zande in Southwest Sudan near the border with Zaire and in other neighbouring areas. There was a high incidence of goitre in the South of Malkal town among the Newair tribe, around A' dammar in the Northern Province and in Darfur in western Sudan. A survey was carried out in 1967 that comprised of 17,470 people in the Darfur province and found that 57.5 % were goitreous, of which 18.5 % had large goitre (Kambal 1969). In the Darfur region of Sudan there was 85.5 % of 7,134 subjects examined, mainly school children, had goitre (Eltom 1984). The prevalence of goitre in the town of Kosti, Central Sudan and the city of Khartoum was investigated on account of the increasing number of goitreous patients in the wards and outpatient clinics of Khartoum Hospital coming from the county of Kosti. The frequency of goitre among 7,173 school children from Kosti was 74.8 % and was higher in girls (82.1 %) than in boys (67.3 %) (Eltom 1984).

The first comprehensive investigation on the cause of endemic goitre in Sudan by measuring the plasma inorganic iodine concentration took place in Khartoum and Darfur provinces in 1971 and concluded that the major cause of endemic goitre in Sudan was iodine deficiency (Greig 1970). Several interventional measures were introduced to control the iodine deficiency disorders problem (Eltom 1985). In 1970, potassium iodide tablets were distributed to elementary school children in Darfur area. Another trial was conducted in the Bara area in the north Kordofan state. Filtration of iodine into well water (Fisch 1993) and fortification of sugar with iodine and Iodised oil supplementation was also tried (Eltom 1995).

Sudan's main source of salt comes from a 56 km long stretch on the coast of the Red Sea. Smaller productions also occur on the north coast; however these are not considered major production sites. It is estimated that Sudan's requirement for iodised salt is in the range of 100,000 to 112,000 tons per year, taking a figure of 4 gram per person per day (Hussein 2006). The national household iodised salt consumption is very poor, not exceeding 11 % (Federal Ministry of Health Sudan 2000). This is reflected in the continued prevalence of goitre in school-going children, the total goitre rate was 22 % (Ministry of Health 2000).

Iodised salt is supplied to the Darfur area and Southern Sudan under the WFP in 2004. The WFP has been supplying iodised salt to about 2.7 million people from 2004 in the Darfur region and 5 million in Southern Sudan (Bani 2005). The Emergency Food Security and Nutrition Assessment survey was conducted in September 2004 in the Darfur region by the WFP in association with US Centre for Disease Control and Prevention, the FAO, UNICEF, Save the Children, the UK and USA and with the support of the Government of Sudan (Mohan 2005). While the situation with regard to production and supply of iodised salt was thus deteriorating, this survey revealed that the prevalence of iodine deficiency disorders among adult women, as reflected in the presence of visible goitre, was as high as 25.5 %.

Figure 1.5. Iodised salt produced and packaged in polyethylene bags

The survey conducted by the Federal Ministry of Health in 1997, shown the highest goitre prevalence in the upper Nile and Kordofan, the areas known with lack of iodine from times of old. However the prevalence in the Red sea (Eastern) and Khartoum was below the expected values (Table 1.6).

Table 1.6. Prevalence of goitre among school children

Regions	Sample Size	Prevalence Rate (%)
Northern	5773	38.1
Eastern	7937	8.2
Khartoum	8165	5.4
Central	7865	22.7
Darfur	4835	27.6
Kordofan	4503	39.1
Upper Nile	1804	42.1
National Total	40,922	22.0

{Source: Federal Ministry of Health 1997}

1.16. AIM OF THE STUDY

The overall aim of this study is to investigate the iodine status of children from the Red Sea (Port Sudan) and Nile Valley (Jabal Awliya) regions of the Sudan and their implications for health and development.

The specific objectives were;

- To determine the status of iodine deficiency disorder in school children aged 6 - 12 years in the Red Sea region (Port Sudan) of the Sudan.
- To determine status of iodine deficiency disorder in school children aged 6 - 12 years in the Nile Valley region (Jabal Awliya) of the Sudan.
- To compare the iodine excretion in urine samples from Red Sea (Port Sudan) and Nile Valley (Jabal Awliya) regions.
- To investigate the intake and the geographical variation of fish consumption.
- To investigate availability and distribution of iodised salt and investigate the iodine content in salt.

CHAPTER 2.

SUBJECTS AND METHODS

2.1. ASSESSMENT OF IODINE STATUS

A cross-sectional of design was used in carrying out this research for descriptive and analytical purposes. Cross-sectional surveys are generally performed to provide representative estimates for a population. Cross-sectional surveys include those that are household-based, school based, or clinic-based. (Zimmerman 2007)

School-age children are a useful target group for iodine deficiency disorders surveillance because of their combined high vulnerability, easy access, and applicability to a variety of surveillance activities. Affected children can be readily examined in large numbers in school settings, and can be assessed for urinary iodine, thyroid size, and thyroglobulin. Urinary iodine is frequently assessed through school surveys (since this is an efficient way to estimate the household iodine nutrition status) or through overall population assessments, as in Domestic Household Survey or Multiple Indicators Cluster Survey. While the median value in a representative sample of school children or the general population provides a reasonable population estimate, it may not reflect the situation in pregnant women, whose iodine requirements are greater, (Zimmermann 2004). Ideally, assessment of iodine status should include concurrent assessment of household use of iodised salt. This provides information on both the likely iodine intake and iodine status, making it easier to distinguish between difficulties with iodised salt quality, and iodised salt use. When adequately iodised salt is used, this should be reflected in adequate iodine status in the population sampled (Manner and Dunn 1995).

2.2. RECRUITMENT AND SAMPLING PROCEDURE

This study was carried out in 2006 in two areas in Sudan (a) the Red Sea region (Port Sudan locality) and (b) Jabal Awliya in the valley of the Nile River, near Khartoum.

Schoolchildren aged 6 to 12 years old were the prime target of the survey (WHO/UNICEF/ICCIDD 2007).

In preparation for a school-based survey, the Ministry of Education provided a listing of all schools in both regions, with the appropriately aged children for the survey (Annex 1).

The sample size in each region was calculated based on the formula set by ICCIDD (1995).

Estimate of the sample size required for this study is determined by the formula used for calculating sample size in cluster surveys.

$$(\text{Sample size, N}) = \frac{Z^2 pq\,(DEFF)}{d^2}$$

p= Estimate of the expected proportion of IDD in the target population (50%)
Z= the level of confidence desired (1.65 for 90% confidence)
q= 1-p = 1-0.5= 0.5
DEFF = the design effect = 2
d=Confidence interval (10%)

$$N = \frac{1.65^2 \times 0.5 \times 0.5 \times 2}{0.1^2} = 136$$

The sample size (N) required for each of the two study regions was 136, however additional 10 children was included as a replacement in case of any absentees. Subsequently the total number of children selected from the both areas was (n = 282).

2.3. GOITRE ASSESSMENT

In each region, a full listing of all primary schools was obtained from the Ministry of Education. The total number of schools in the region was divided by the required number of clusters to determine the sampling interval (k). The starting point for selection of the first cluster or school was determined by selecting a random number between 1 and k. Then the remaining schools were selected by systematic random sampling using the calculated sampling interval. Lists of the selected schools in the two regions (12 schools) were then prepared for fieldwork.

Forms were designed for collection of data from the selected students and for recording lab test results, the first form was an interview questionnaire for the children's personal data (Identification data). The second form was for recording the results of the rapid test kit for iodine in salt, whether negative, <15 ppm or 15+ ppm or excessive, It also served to record the receipt of a valid urine sample from the schoolchild. The third form was used for collecting data on fish consumption, and the fourth form was for recording the results of the lab tests for iodine content in urine and in salt.

To collect the urinary specimen, the survey team member provided each child with a disposable plastic cup and requested him or her go into the bathroom and urinate directly into the cup. The number assigned to the child at registration was written on the collection cup. All measures were taken to ensure supervision of children to make sure they do not share urine specimens or add other fluids to the sample.

A sample of urine was collected from every child and divided into 3 aliquots: Sample 1 and Sample 2 and sample 3. A urine sample was first collected from every child in a sterile pre-labelled capped cup. With a disposable pipette, the lab technician transferred at least 2 ml of urine to each of the three pre-labeled vials and screwed the caps on tightly. One sample was kept as reference in the central lab in Sudan. The second and third samples were packed in sealed plastic bags and then kept into a transport box (a sealed container). This sealed container was delivered to the central collection unit in Khartoum, and shipped to the international Iodine Network Lab, Nutrition intervention unit at the Medical Research Centre (MRC) in Cape Town, South Africa for analysis.

Proper shipping and storage of urine specimens was carefully considered to ensure that the iodine level in specimens remained stable until the time of analysis. All urine specimens were airmailed frozen to the laboratory in South Africa in an insulated shipping container on dry ice.

At the end of collection process, we reviewed the information on each child's form to assure that it is complete and correct. This was performed while the children were present to make sure that information was verified or corrected.

Training was provided to the survey team members to assure that they know exactly what they need to do to collect demographic information, salt and urine specimens. This included training on how to collect demographic information, how to test iodine in salt with Rapid Test Kits, how to request a participant to provide a urine specimen, how to handle the specimen, how to pipette the specimen into tubes, and how to label the tubes with urine and salt samples in plastic bags, and how to ship the specimens properly. Copies of the Guidelines on handling of samples and Safety precaution recommended by ICCIDD are provided in Annex 3 and Annex 4, respectively.

Parents of a child selected for a survey were requested to sign Informed Consent Statement and provide a child with a sample of salt for the survey.

2.4. URINARY SPECIMEN FOR TESTING IODINE CONTENT

Most iodine absorbed by the body eventually appears in the urine. Therefore, urinary iodine excretion is a good marker of very recent dietary iodine intake. In individuals, urinary iodine excretion can vary somewhat from day to day and even within a given day (Dunn1993). Studies have convincingly demonstrated that a profile of iodine concentrations in the morning or other casual urine specimens (child or adult) provides an adequate assessment of a population's iodine nutrition, as long as a sufficient number of specimens are collected (Dunn, Myers; 1998). Round the clock urine samples are difficult to obtain and are not necessary. Relating urinary iodine to creatinine, as has been done in the past, is cumbersome, expensive, and unnecessary. Indeed, urinary iodine/ creatinine ratios are unreliable, particularly when protein intake – and consequently creatinine excretion – is low.

2.5. METHOD FOR MEASURING URINARY IODINE USUING AMMONIUM PERSULFATE

- Principle

Urine is digested with ammonium persulfate. Iodide is the catalyst in the reduction of ceric ammonium sulphate (yellow) to the cereous form (Colourless) and is detected by the rate of colour disappearance (Sandell- Kolthoff reaction).

- Equipment

Heating block with a temperature range up to 110°C or above (vented fume hood recommended, but not essential); spectrophotometer; thermometer, test tubes (13 x 100 mm); assorted glassware and storage bottles; pipettes; vortex; magnetic hotplate; magnetic stirrer; analytical balance or top loader scales with a readability of at least 0.001 g and a capacity of approximately 250 g.

- Reagents

1. Ammonium persulfate (H8n2o8s2)
2. Arsenic trioxide ($As2O_3$)
3. Sodium chloride (NaCl)
4. Sulphuric acid (H_2SO_4)
5. Sodium hydroxide (NaOH)
6. Ceric ammonium sulphate [Ce (NH4)4(SO4)4•2H2O]
7. Deionised water (H_2O)
8. Potassium iodate (KIO_3)

- Solutions

Ammonium persulfate (1.0 mol/l) - Dissolve 114.1 g ammonium persulfate in 500 ml deionised water. Store in refrigerator.

5 N Sulphuric Acid - Add 140 ml concentrated (36 N) sulphuric acid slowly to about 700 ml deionised water. When cool, adjust with deionised water to a final volume of 1 litre.

3.5 N Sulphuric acid - Add 97 ml concentrated (36 N) sulphuric acid slowly to about 700 ml deionised water. When cool, adjust with deionised water to a final volume of 1 litre.

Sodium hydroxide (0.875 mol/l) - Dissolve 17.5 g sodium hydroxide pellets in 500 ml deionised water.

Arsenious acid solution (0.05 mol/l) - Dissolve 10 g arsenic trioxide in 200 ml of 0.875 mol/l sodium hydroxide solution. Slowly add 32 ml of concentrated (36 N) sulphuric acid to the solution in an ice bath while stirring. After cooling, add 25 g of sodium chloride and then adjust to 1 litre with cold deionised water with stirring to dissolve and store in darkness, stable for months.

Ceric ammonium sulphate solution (0.038 mol/l) - Dissolve 24 g ceric ammonium sulphate in 1 litre 3.5 N H_2SO_4. Make up at least 24 h before use, and store in darkness; stable for months.

Standard iodine solution (KIO_3):

Stock standard A - Dissolve 0.840 g potassium iodate in deionised water to a final volume of 500 ml in a volumetric fl asks. This solution is equivalent to 1000 μg/ml.

Stock standard B - Dilute 5 ml of standard A in deionised water to a final volume of 500 ml in a volumetric fl ask. This solution is equivalent to 10 μg/ml. Store all stock standards in white or brown plastic bottles, in a refrigerator away from light. The solution is stable for 6-12 months.

Working standards - Prepare by adding aliquots of 200, 400, 800, 1200, 2000, and 3000 μl of standard B, each diluted with water to a final volume of 100 ml in volumetric flasks. These standards are equivalent to iodine concentrations of 20, 40, 80, 120, 200, and 300 μg/l. Include a zero standard (deionised water). Store in plastic bottles in a refrigerator away from light. Stable for 1-3 months.

Note: 1.68 mg KIO_3 contains 1.0 mg iodine. 1000 µg iodine/l is equivalent to 7.9 µmol/l.

- Procedure

1. Allow urine to reach room temperature, and then mix urine to suspend sediment.
2. Pipette 250 µl of each urine sample, working standards ranging from 0 to 300 µg/l and internal urine controls, into 13 x 100 mm test tubes. Duplicate iodine standards and a set of internal urine controls should be included in batch.
3. Add 1 ml ammonium persulfate to each tube.
4. Heat all tubes for 60 minutes at 91-95 °C.
5. Cool tubes to room temperature.
6. Add 2.5 ml Arsenious acid solution. Mix by inversion or vortex. Let stand for 15 minutes.
7. Add 300 µl of ceric ammonium sulphate solution to each tube at 15 to 30-second intervals between successive tubes, mixing each with a vortex after addition. A stopwatch should be used for this. With practice, a 15-second interval is convenient.
8. Allow to sit at room temperature. Exactly 30 minutes after the addition of ceric ammonium sulphate to the first tube, read its absorbance at 405 or 420 nm. Read successive tubes at the same time intervals as when adding the ceric ammonium sulphate.

- Calculation of results

A standard curve constructed by plotting the log of the absorbance at 405 nm on the X-axis versus the standard iodine concentration in µg/l on the Y-axis with a scatter plot, using Excel on a desktop computer. The iodine concentration in µg/l of each specimen is calculated by using the equation of the linear trend line of this chart. As this is an inverse endpoint colour reaction, all specimens that have absorbance values lower than the acceptable standard curve (or calculate concentration >300 μg/l) should be diluted, preferably 1:3 or 1:5 dilutions, or as required, with water and re-essayed.

2.6. INDICATORS OF IODINE DEFICIENCY DISORDERS ASSESSMENT

Table 2.1. Epidemiologic criteria for assessing iodine nutrition based on median urinary iodine concentrations in school children

Median Urinary iodine (μg/l)	Iodine intake	Iodine Nutrition
< 20	Insufficient	Severe iodine deficiency
20 – 49	Insufficient	Moderate iodine deficiency
50 – 99	Insufficient	Mild iodine deficiency
100 – 199	Adequate	Optimal
200 – 299	More than adequate iodine intake	Risk of Iodine – induced hyperthyroidism within 5- 10 years following introduction of iodised salt in susceptible groups
>300	Excessive Iodine Intake	Risk of adverse health consequences (Iodine-induced hyperthyroidism, autoimmune thyroid disease)

{Source: Assessment of iodine deficiency disorders and monitoring their elimination. Guideline for programme managers, WHO/UNICEF, Third edition, 2007}

Table 2.2. Indicators of assessment (Criteria for monitoring iodine deficiency disorders situation)

Indicator	Goals
Proportion of urinary iodine below 100 ug/L	< 50%
Proportion of urinary iodine below 50 ug/ L	< 20%
Median in the general population	100–199 µg/l
Median in pregnant women	150–249 µg/l
Proportion of households using adequately iodised salt (>15 ppm - < 40 ppm)	90 %

{Source: Assessment of iodine deficiency disorders and monitoring their elimination. Guideline for programme managers, WHO/UNICEF, Third edition, 2007}

For lactating women and children <2 year of age a median urinary iodine concentration of 100 (µg/l) can be used to define adequate iodine intake, but no other categories of iodine intake are defined. Although lactating women have the same requirements as pregnant women, the median urinary iodine is lower because iodine is excreted in breast milk.

Table2.3. Epidemiological criteria for assessing iodine nutrition based on the median or range in urinary iodine concentration of pregnant women

Median urinary iodine concentration (µg/l)	Iodine intake
<150	Insufficient
150-249	Adequate
250-499	Above requirement
>500	Excessive

{Source: Assessment of iodine deficiency disorders and monitoring their elimination. Guideline for programme managers, WHO/UNICEF, Third edition, 2007}

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Table 2.4. Simplified classification of goiter by palpation

Grade 0	No palpable or visible goiter
Grade 1	A goiter that is palpable but not visible when the neck is in the normal position (i.e. the thyroid is not visibly enlarged). Thyroid nodules in a thyroid, which is otherwise not enlarged, fall into this category.
Grade 2	A swelling in the neck that is clearly visible when the neck is in a normal position and is consistent with an enlarged thyroid when the neck is palpated.

{Source: Assessment of iodine deficiency disorders and monitoring their elimination. Guideline for programme managers, WHO/UNICEF, Third edition, 2007}

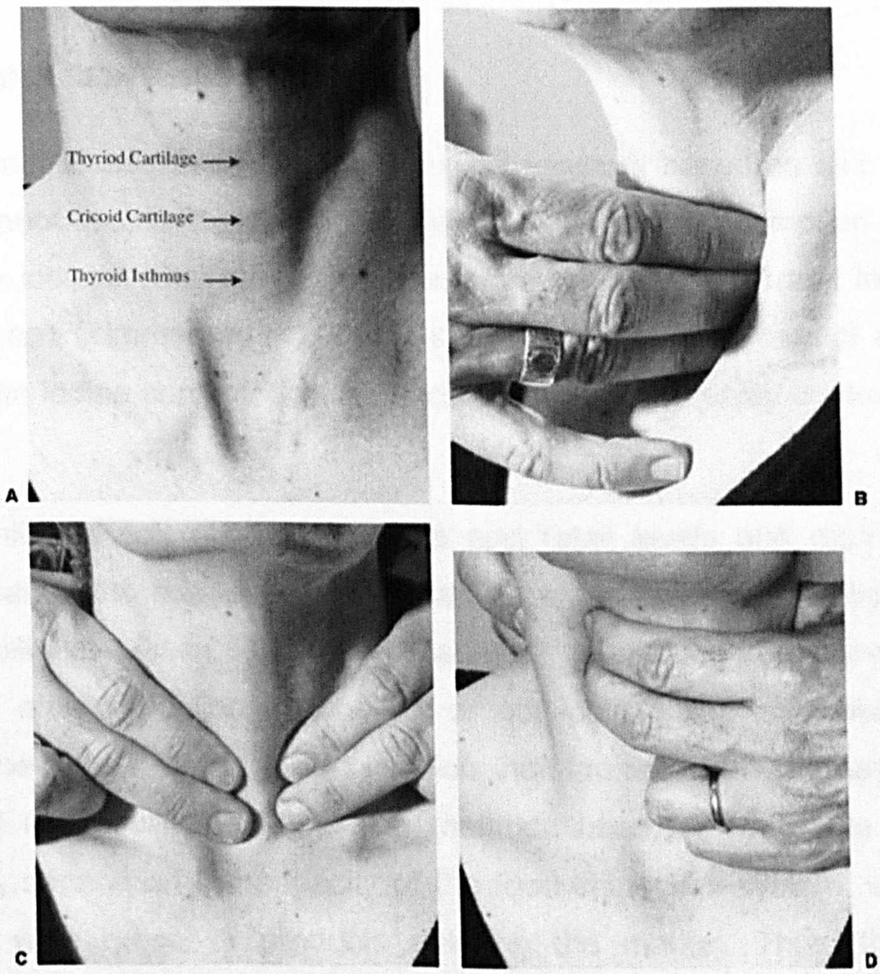


Figure 2.1. Physical examination of the thyroid gland. A: Landmarks in the physical exam of the thyroid. B: Examination of the thyroid facing the patient, with the fingers of the right hand on the left lobe of the thyroid. C: Examination of the thyroid from behind the patient. Here, fingers of each hand palpate both thyroid lobes simultaneously. D: Examination of the neck for the presence of lymphadenopathy along the left sternocleidomastoid muscle.

Table 2.5. Procedures performed in this survey

Procedure	Purpose
Palpation of neck	Goitre examination
Casual urine sample	Iodine excretion
Food frequent questionnaire	Intake of fish, intake of iodine rich food intake including iodised salt, intake of goiterogenic rich food
Personal interview	Thyroid disease, use of medications

{Source: Assessment of iodine deficiency disorders and monitoring their elimination. Guideline for programme managers, WHO/UNICEF, Third edition, 2007}

2.7. IODINE CONTENT OF SALT

An iodine deficiency disorders control program based on salt iodisation clearly cannot succeed unless all salt for human consumption is being adequately iodised (Sullivan 1995). Therefore the most important indicator to monitor is salt (Zimmermann 2005). Since Rapid Test Kits cannot accurately measure the iodine content, titration should be used for quality control (Pandav 2000).

Monitoring salt at the wholesale and retail levels and monitoring the iodine in salt at the retailer level provides an answer to the question: "What is the availability of iodised salt to the consumer?" Monitoring at this level yields a quick and easy indication of whether or not iodised salt is available in the marketplace, and the degree to which non-iodised salt is competing for household use (Sullivan 1995). The methods used for wholesale and retail monitoring depend on the capacity of the food inspection system, which often covers a wide range of products entering the market. Thus, there is no prescribed sampling method at this level, and countries have widely variable capacity and have used many approaches (WHO/UNICEF 2004).

In order for school or household surveys to accurately represent the populations from which the sample is taken, attention must be given to the sampling methodology (Gorstein 2006.).Guidelines on handling of samples and safety measures are provided in Annex 3 and 4.

2.8. FOOD FREQUENCY QUESTIONNAIRE

Forms were designed for collection of data from the selected children and for recording lab test results. The first form was an interview questionnaire for the children's personal and socio demographic data. Data were collected through interviews using this simple form. Apart from identification data for the child and the interviewer, the form involved questions on fish consumption and the rate. The second form was used for recording the results of the lab tests for iodine content in urine and in salt.

A unique identifier was set for each child based on school, and the child identification number in the class listing. This composite number was printed on five sticker labels, which were used to identify each child's interview form, lab form, salt sample, and two urine samples.

The following procedures were adopted to collect data on socio demographic, salt and urine specimen collection and thyroid gland palpation.

a- Household Knowledge, Attitude and Practice Questionnaire

Children were trained and instructed to deliver the Questionnaire form to their parents, answer the questions and bring it back to school. This was done under our supervision and of the headmaster and school health supervisor. The questionnaires were mainly on fish consumption.

b - Salt specimen collection and testing.

Each child was asked to bring a sample of salt from home (2 tablespoons) on the day of the survey. Half of the salt that was provided was tested using Rapid Test Kits.

2.9. DATA ANALYSIS

In a situation which the number of samples is small, for example 100 or so, then processing by hand is fairly easy. With large numbers of data, such as those from a cluster survey of urinary iodine where there may be over 900 results, use of a personal computer makes processing those data much easier.

Data should be entered using a suitable program. Possibilities include a spreadsheet containing a special module for analysis of cluster sampling (Dean, 1994). Theoretically, data should be importable from one to the other, but in practice this is not always easy. Requirements involve deriving a measure of central tendency and a measure of variability, or spread of the distribution. Unfortunately, many iodine deficiency disorders parameters are not normally distributed. Rather, the results may be highly skewed in one direction. For example, the distribution of both urinary iodine and thyroid size values are typically skewed to the right (positively skewed). The upper tail of the distribution is longer than the lower tail. In such cases, the use of means and standard deviations to summarize the data is inappropriate, and non-parametric methods should be used to summarize and compare distributions (Dunn 1993). The median (which is simply the middle value of the distribution) is used as the measure of central tendency. The median is the same thing as the 50th percentile. Half the results in the distribution are above the median and half are below. It is equidistant from either extreme. A useful way of describing a spread of values, which is not normally distributed, involves the use of selected percentiles. The value of the 20th and 80th percentiles (first and fourth quintiles) would be suitable, and would give a sense of shape to the distribution of values. However, it has been customary practice in giving the results of iodine deficiency disorders surveys to use cut-off points to delineate the lower tail of the distribution. For example, in a frequency distribution of urinary iodine values, it is helpful to indicate the numbers and proportion below set values typically (100, 50 and 20 mg/l). After iodine prophylaxis has been introduced, it may also be helpful to indicate the proportion of values above a particularly high level (e.g. 500 mg/l). It is important not to over interpret the results obtained. For example, it is a common fallacy to say that all children with a spot urine iodine value below 100 mg/l are iodine deficient. If the median is 100 mg/l, then by definition half of the values will be below this level. Individual spot urine iodine values are likely to be highly variable over time. It should be noted that in carrying out a survey, only a sample of individuals is examined - not the entire population. There will therefore inevitably be a degree of sampling error in the results obtained. This is decreased - but not eliminated - by increasing the sample size, but this also increases cost. The use of confidence intervals gives an idea of the range in which the true population value is likely to lie. Ninety-five percent confidence intervals can be calculated for a median, and should be quoted alongside the value itself (Gorstein 2006).

In compiling overall results of iodine deficiency disorders surveys, e.g. at the national level, it is important not to simply take averages of sub-national data. By so doing, the overall result obtained may be biased. Rather, the following guidelines are useful: Results from prevalence surveys in different regions should be weighted according to population size, before combining them. The total enrolment of all schools in the region, or the total population of the region, should be used to make this adjustment. Urinary iodine values and thyroid volumes from ultrasound should be treated in a similar way. These are both numerical variables, as compared to presence or absence of goiter, which is a categorical variable (Binkin 1992).

CHAPTER 3.

IODINE STATUS OF CHILDREN LIVING IN THE RED SEA REGION (PORT SUDAN) OF SUDAN

3.1. RED SEA REGION - POPULATION AND GEOGRAPHY

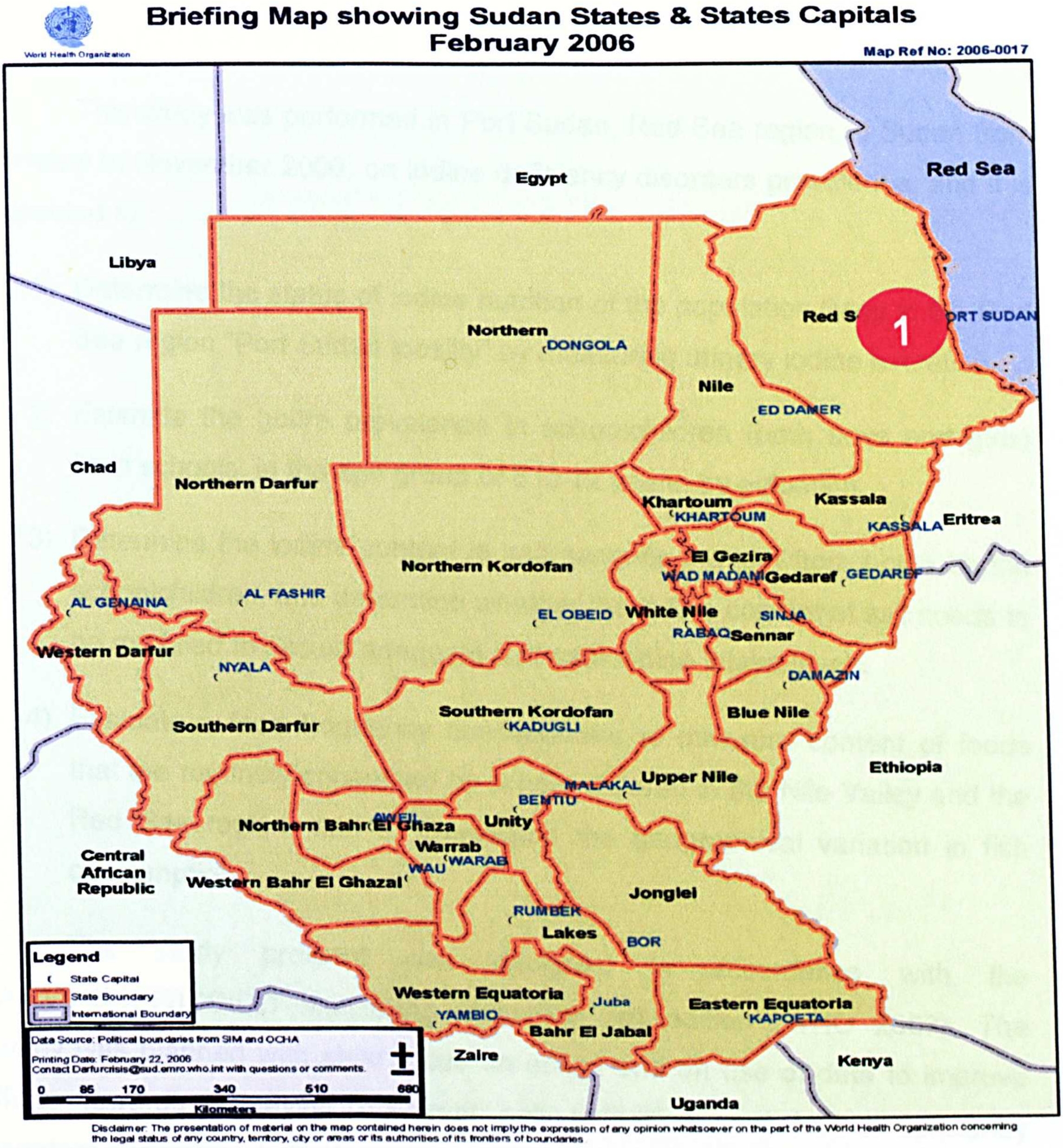
The Red Sea is one of the 26 Wilayat or states of Sudan. It has an area of 218,887 sqare km and an estimated population of approximately 700,000 (Federal Ministry of Health Sudan 2000). Port Sudan is the capital of the State of Red Sea and has nearly 300,000 residents. Located on the Red Sea it is the republic of Sudan's main port city. The British founded it in 1905 as the terminus of a rail line linking the river Nile.

The number of health facilities exceeds 193, with 140 primary schools for both sexes. Port Sudan has a near-desert climate, requiring the acquisition of fresh water from Wadi Arba'at in the Red Sea Hills and from salt evaporating pans (Federal Ministry of Health Sudan 2000). The weather is uncomfortable in the summer due to heat and humidity, and unlike most Sudan; rainfall occurs in winter. Almost all of Sudan's salt is produced along the coast by solar evaporation of Red Sea brine (Hussein 2000). Inquiries in Khartoum and Port Sudan from the Government offices and major salt producers reveal that there are a number of salt producing units along the Red Sea Coast. In Port Sudan area there are 11 salt producers (Mohan 2005).

The Red Sea region is characterized by chronic underdevelopment, widespread poverty and marginalization of large strata of the population. The nutritional status of the population, support to the most vulnerable, and access for health care, especially for women and children are a matter of concern. The Red Sea state is also characterized by the presence of a large number of internally displaced persons with about 120,000 in Port Sudan and these need support from the humanitarian community. Also the refugees in camps continue to receive food rations by World Food Program (Bottigliero 2002).

The location of Port Sudan, Red Sea region is illustrated in the the map of Sudan in Figure 3.1.

Figure 3.1. Map of Sudan and location of study area (1-Port Sudan)



{Source: WHO 2006}

3.2. SELECTION METHODS

This study was performed in Port Sudan, Red Sea region of Sudan from January to November 2006, on iodine deficiency disorders prevalence, and it is expected to:

1) Determine the status of iodine nutrition of the population living in the Red Sea region "Port Sudan locality" by measuring urinary iodine excretion.
2) Estimate the goitre prevalence in schoolchildren (both boys and girls) from schools, in the age group of 6 to 12 years, by palpation.
3) Determine the iodine content in salt samples brought from home by the schoolchildren, and determine whether the iodine content of salt needs to be modified to assure adequate and safe iodine intake levels.
4) Evaluate a food frequency questionnaire to measure content of foods that are routinely consumed by school children in the Nile Valley and the Red Sea region; and to investigate the geographical variation in fish consumption.

The study protocol was designed in accordance with the WHO/UNICEF/ICCIDD Monitoring Guideline 3rd edition (WHO 2007). The survey was planned with clear focus on action and on use of data to improve efforts towards achieving universal salt iodisation and iodine deficiency disorders elimination in Sudan.

Cross-sectional design was used in carrying out this study for descriptive and analytic purposes. A probability-proportional-to-size (PPS) sampling method was used to obtain a representative sample of 141 school children aged 6 - 12 years old. A full list of all primary schools was obtained from the Ministry of Education and 6 schools (3 for boys and 3 for girls) were randomly selected. In the first stage, six primary schools were selected (Table 3.1). In the second stage, 1 to 2 classes were randomly selected from each school depending on the number of students per class. A total of 141 children were recruited. The mean age was 9.8 years (Table 3.1). All selected children (n=141) brought salt samples from their houses (Table 3.2). The list of primary schools obtained from the ministry of Education is provided in Annex 1.

Table 3.1. Summary information on surveyed schools (Port Sudan)

Code	School Name	No. of children surveyed	Mean age (years)
1	Al-Wihda Sharig for Boys	23	
2	Daim Arab for Boys	24	
3	Alfarouq for Boys	24	
4	Um Alqura for Girls	23	
5	Alingaz for Girls	23	
6	Alingaz "A" for Girls	24	
	TOTAL	141	9.8

Table 3.2. Number of salt samples collected from school in Port Sudan

Code	School name	Salt samples collected (*n*)
1	Al-Wihda Sharig for Boys	23
2	Daim Arab for Boys	24
3	Alfarouq for Boys	24
4	Um Alqura for Girls	23
5	Alingaz for Girls	23
6	Alingaz "A" for Girls	24
	Total	141

3.3. DEMOGRAPHIC QUESTIONNAIRE

Forms were designed for collecting data from the selected children and for recording lab test results. The first form was an interview questionnaire for the children's personal and socio-demographic data. Data was collected through interviews using this simple form. Apart from identification data for the child and the interviewer, the form involved questions on fish consumption and the rate. A copy of the questionnaire form is provided in Annex 2. The second form was used for recording the results of the lab tests for iodine content in urine and in salt.

A unique identifier was set for each child based on school, and the child identification number in the class listing. This composite number was printed on five sticker labels, which were used to identify each child's interview form, lab form, salt sample, and two urine samples.

The following procedures were adopted to collect data on socio-demographic, salt and urine specimen collection and thyroid gland palpation

3.4. FOOD FREQUENCY QUESTIONNAIRE

Household Knowledge, Attitude and Practice Questionnaire

- Children were trained and instructed to deliver the Questionnaire form to their parents, answer the questions and bring it back to school. This was done under the supervision of the headmaster and school health supervisor.

Salt specimen collection and testing

- Each child was asked to bring a sample of salt from home (2 tablespoons) on the day of the survey. Half of the salt that was provided for test using Rapid Test Kits.

3.5. BIOCHEMICAL AND CLINICAL ASSESSMENT METHODS

One member of each team had received training in the recognition of visible goitre by the use of palpation assessed goitre. The size and consistency of the thyroid gland were carefully noted. When necessary, the subjects were asked to swallow (e.g. some water) when being examined as the thyroid moves up on swallowing. The size of each lobe of the thyroid is compared to the size of the tip (terminal phalanx) of the thumb of the subject being examined.

A sample of urine was collected from every child and divided into two aliquots: Sample 1 and Sample 2. A urine sample was first collected from every child in a sterile pre-labelled capped cup. With a disposable pipette, the lab technician transferred at least 5 ml of urine to each of the two pre-labelled vials and screwed the caps on tightly. Urine samples were shipped to the Medical Research Centre (MRC), in Cape Town, South Africa (International Laboratory Network for Iodine), where the urine samples were tested for urinary iodine content using the ammonium persulfate method. Quality control was provided by MRC, according to the WHO/UNICEF/ICCIDD approved protocols. The indicators of iodine deficiency disorders assessment are provided in Chapter 2 (Table 2.1. to 2.5.).

Urine tubes were stored in vaccine boxes at 0 to 5 C until the end of the day, when they were transferred to a freezer for storage at -5 to -15 C. Samples were shipped on wet ice through DHL for analysis to the Nutritional Intervention Research Unit, Medical Research Council, South Africa (MRC).

Iodine concentrations in salt samples were measured by titration. Iodine was released from an aqueous solution of the salt sample by the addition of dilute sulphuric acid and quantified by titration with a solution of sodium thiosulphate, using starch as the indicator (ROSCA 1998).

3.6. CAPACITY BUILDING

A two-day training workshop was conducted in preparation of the survey in Port Sudan. The training programme included introduction of iodine deficiency disorders control program, the survey methodology and the using indicators of the assessment (Tables 2.1, 2.2, 2.3, 2.4, 2.5). The participants were also trained on collection of urine and salt samples, use of rapid test kits, and assessment of goitre by palpation.

3.7. QUALITY CONTROL

For quality control and verification, a field, office and lab quality control procedures were followed at the various stages of the study. For field quality control: a citizen and a focal point from the Federal Ministry of Health were assigned for each school. They were responsible for checking the completion, accuracy and consistency of the forms, and for checking the labelling and suitability of salt and urine samples.

Lab quality control: All instructions by the Medical Research Centre laboratory in Cape Town (affiliated lab to International Iodine Network Laboratories). All samples were kept in the specially provided refrigerator and transported following carefully the guidelines of WHO and DHL.

Data were cleaned upon completion of data entry. This involved creating summary tables with minimum and maximum values, frequencies and cross-tabulation. In the event that any outlying values were detected, they were ascertained from the original forms.

3.8. STATISTICAL ANALYSIS

Data are presented using descriptive statistics in the form of frequencies and percentages for qualitative variables and means, medians and standard deviations for quantitative variables. Tabular and graphic presentations were used as appropriate.

To calculate descriptive analyses, we entered the set of data we obtained in the data editor. Once the data are in data editor, we were able to calculate, for each group, the mean, and standard deviation, minimum, and maximum, variance, range, and skewness of each group. T-test was used to compare qualitative variables.

The data are presented as mean ± standard deviation (SD). All data analyses were performed with statistical package SPSS for windows (version 13).

3.9. RESULTS

This study was first of its type after the introduction of the salt iodisation programme in Sudan. The overall aim of the study is to contribute to the assessment of the status of iodine nutrition in Sudan and support the efforts towards the elimination of Iodine Deficiency Disorders in the country. This was achieved through assessment of the status of iodine deficiency disorders (IDD) in school children aged 6 - 12 years, in the Red Sea region of the Sudan and in the Nile valley region of the Sudan.

The assessment was carried out by measuring the urinary iodine level of primary-school children, and the salt content of iodine and Goitre prevalence using palpation, and questionnaire on the fish intake and the geographical variation consumption.

3.9.1. Urinary Iodine Concentration

Of the 141 children recruited, the data from 140 (70 boys and 70 girls) are used for statistical analysis, hence all data presented below is based on a total number of 140. The median urinary iodine of the study sample in the Port Sudan was 555.2 µg/L, and the mean urinary iodine was 587.1 µg/L (standard deviation of 327.8). There was no difference in the mean urinary iodine concentration between six schools, with an exception of Daim Arab for Boys and Alingaz for Girls (Table 3.3). The urinary iodine concentration from Alingaz for Girls was significantly lower compared with that of Daim Arab for Boys ($p=0.002$). Only 0.7% of samples were below 50 µg/L, and only 6% had the adequate intake (100 - 200 μg/L). Above 92 % of the studied samples had iodine concentration more than adequate (above 200 μg/L) (Fig 3.2.).

Table 3.3. Urinary iodine concentration (UIC) of children from six schools in Port Sudan (mean ± SD μg/L)

Code	School name	(*n*)	UIC (μg/L)
1	Al-Wihda Sharig for Boys	23	609.2 ± 312.6
2	Daim Arab for Boys	24	771.4 ± 324.7
3	Alfarouq for Boys	24	539.0 ± 302.7
4	Um Alqura for Girls	23	656.9 ± 263.9
5	Alingaz for Girls	23	409.6 ± 269.4
6	Alingaz "A" for Girls	24	531.1 ± 388.6
	Total	141	587.1 ± 327.8

Figure 3.2. Distribution of the urinary iodine (μg/L) in the samples from Port Sudan according to the WHO Criteria

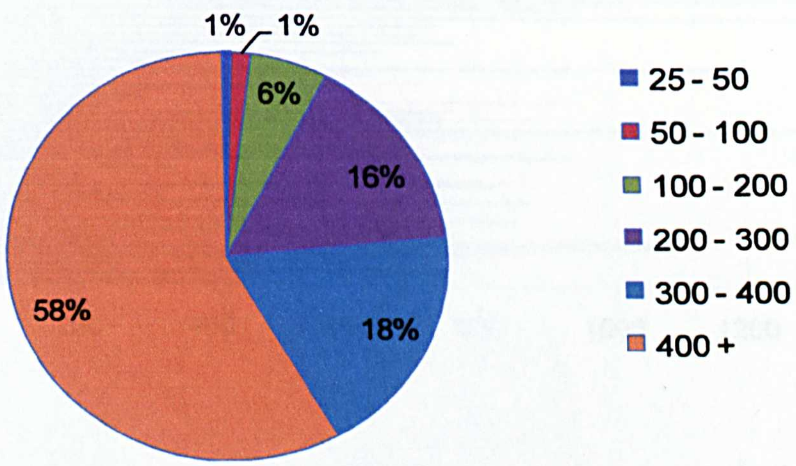


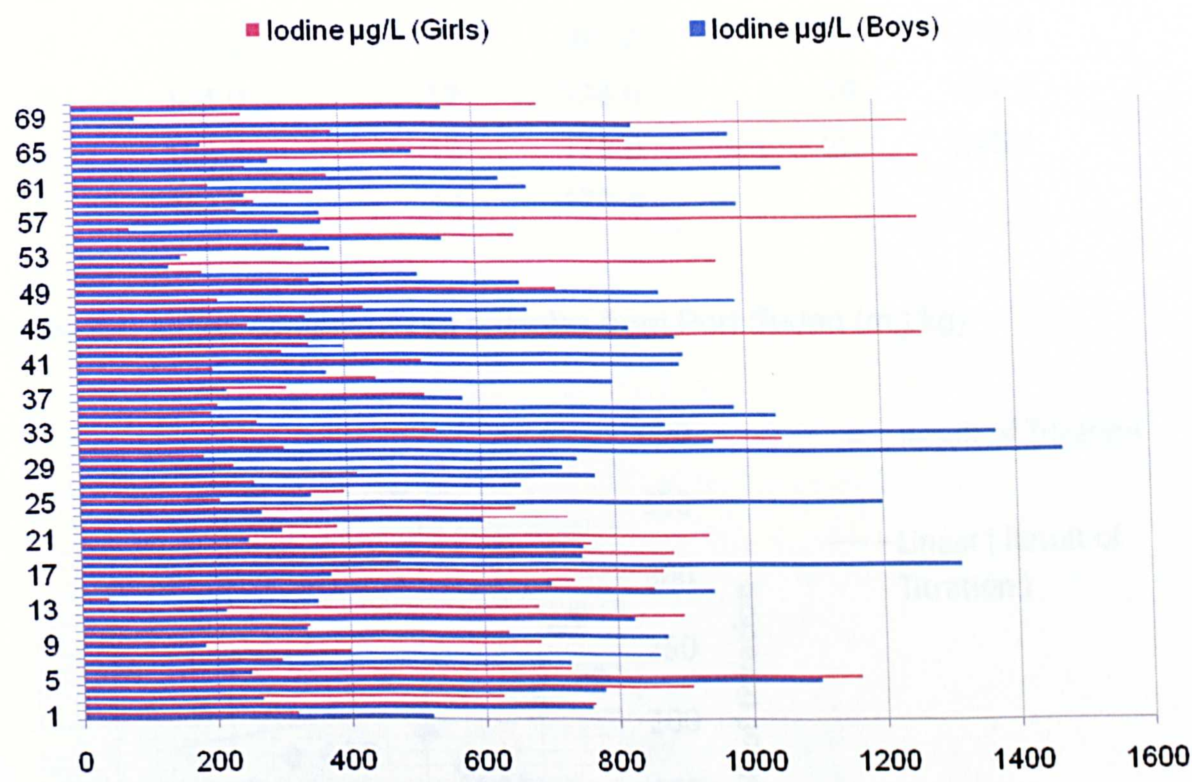
Figure 3.2 indicates that only 16% of the studied samples had iodine concentration between 200-300 μg/L, and 18% had iodine concentration between 300 – 400 μg/L, and 58% had iodine concentration above 400 μg/L. The minimum level of urinary iodine was 38 μg/L and the highest urinary iodine

level was 1470 µg/L, and range of 1432 µg/L. The result clearly shows the excessive intake of iodine in children living in Port Sudan.

3.9.2. Urinary Iodine Concentration by Gender

The male gender scored higher urinary concentration than the female gender. The highest level scored by male gender was 1470 µg/L, whereas the lowest level 31.7 µg/L was scored by female gender. The chances for adequate food are higher in males than female gender in the region.

Figure 3.3. Distribution of urinary iodine concentration by gender



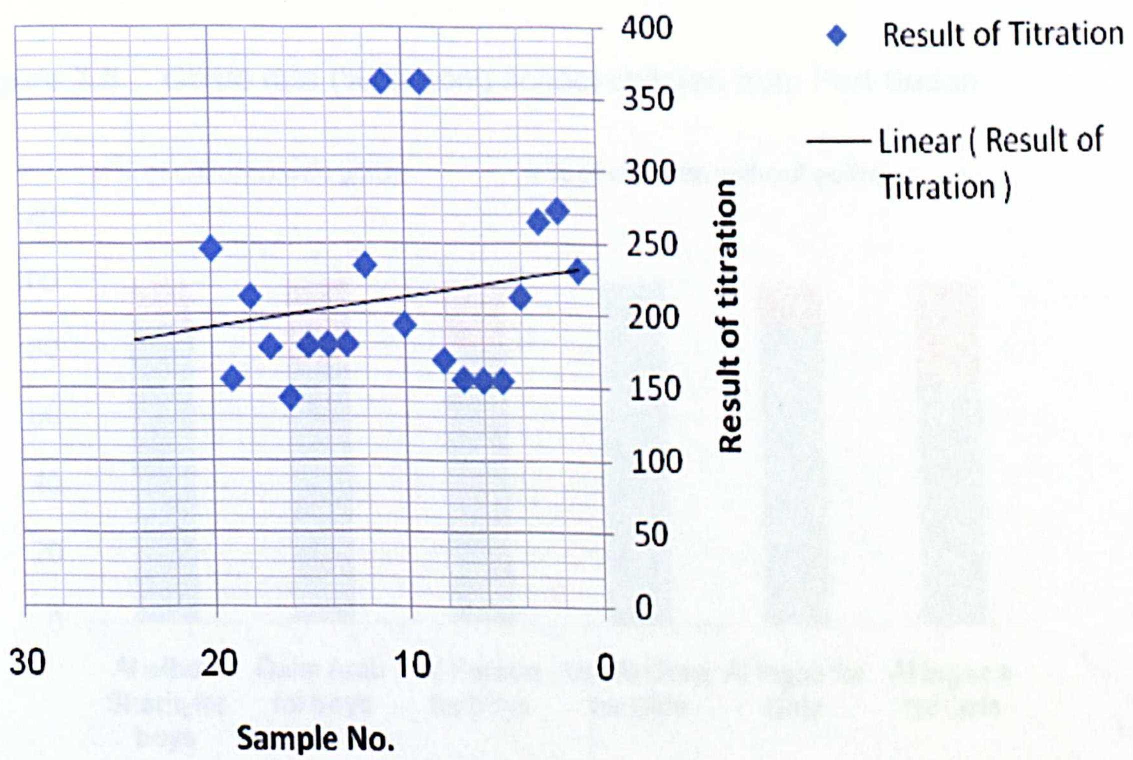
3.9.3. Levels of iodine in the salt consumed in Port Sudan

The iodine content of salt consumed by children living in the Rea Sea region is provided in Table 3.4. The result has revealed that the children of Port Sudan consume excessive amount of iodine. It has also revealed a great fluctuation in the iodine content of salt. The quantity of potassium iodate varied between 141 mg/kg and 361 mg/kg. The lowest level of the positive values was 141.9, which is in excess by 9.4 times than the lowest recommended level of (15 ppm). The highest level of iodine content of salt recorded was 361.1; this is also in excess by 9.0 times compared to the highest recommended level of (40 ppm).

Table 3.4. Iodine content of salt samples (KIO_3, mg/kg) using titration method

Sample No	KIO_3 (mg/kg)	Sample No	KIO_3 (mg/kg)	Sample No	KIO_3 (mg/kg)
1	230.6	8	168.1	15	178.0
2	272.0	9	361.0	16	141.9
3	264.3	10	192.5	17	176.9
4	212.0	11	361.0	18	212.0
5	154.0	12	234.0	19	154.8
6	154.1	13	179.0	20	245.1
7	154.8	14	179.0		

Figure 3.4. Iodine content of salt samples from Port Sudan (mg/kg)



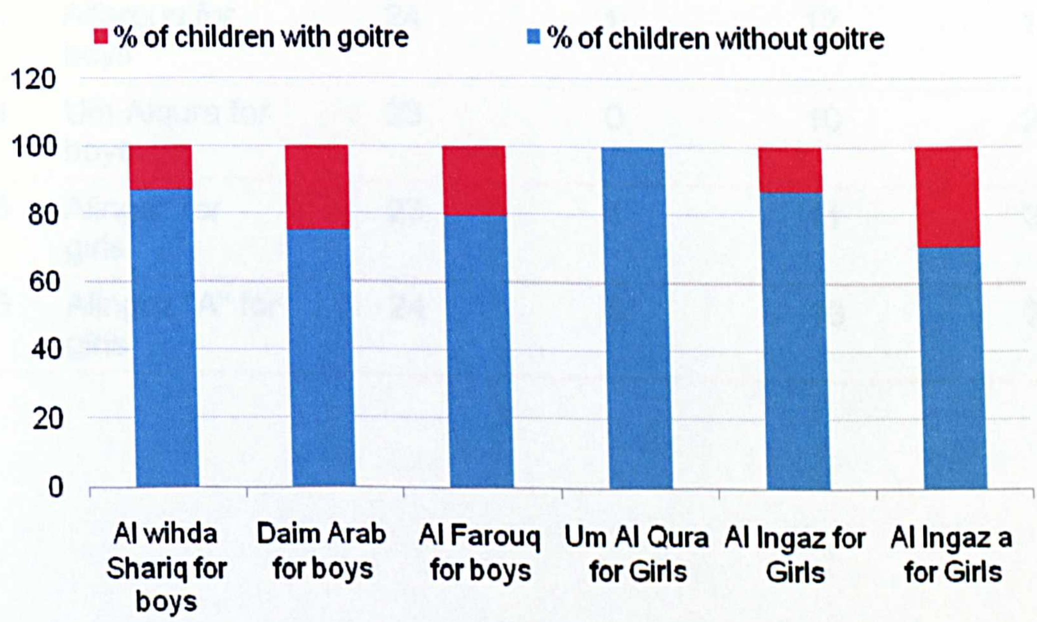
3.9.4. Goitre Rate

The goitre rate among school children in Red sea region was 17 % and its prevalence was higher in boys (19.7 %) compared to girls (14.3 %) (Table 3.5, Fig 3.5).

Table 3.5. Goitre rate among school children from Port Sudan

Code	School name	Total no. of children investigated (*n*)	No. of children with goitre (*n*)	%
1	Al-Wihda sharig for boys	23	3	19.7 (boys)
2	Daim Arab for boys	24	6	
3	Alfarouq for boys	24	5	
4	Um Alqura for girls	23	0	14.3 (girls)
5	Alingaz for girls	23	3	
6	Alingaz "A" for girls	24	7	
	Total	141	24	17

Figure 3.5. Goitre rate (%) among school children from Port Sudan



3.9.5. Fish Intake

Only 1.43 % of children have reported that they ate fish at least once a week (Table 3.6, Fig. 3.6). Moreover, as shown in Fig 3.7., the fish intake by children living in Port Sudan is minimal by both sex, but the intake among the teachers in the same region was relatively higher (14 %). We have also noted that all teachers were recruited from outside of the Red Sea region which is quite common practice in Sudan. Interestingly, 10 (14 %) out of 70 teachers participated in the survey reported that they eat fish at least once a week. Although fish is abundantly available, the influence of the teachers on school children behaviour to consume or eat fish was nil. We have found no significant different between male and female in fish intake.

Table 3.6. Fish intake among school children and teacher from Port Sudan

No	School name	Total children interviewed	No. of children consuming fish	No. of teachers interviewed	No. of teachers consuming fish
1	Al-Wihda sharig for boys	23	0	14	3
2	Daim Arab for boys	24	0	11	0
3	Alfarouq for boys	24	1	12	1
4	Um Alqura for boys	23	0	10	2
5	Alingaz for girls	23	1	11	3
6	Alingaz "A" for girls	24	0	13	2

Figure 3.6. Percentage of fish intake among school children and teachers from Port Sudan

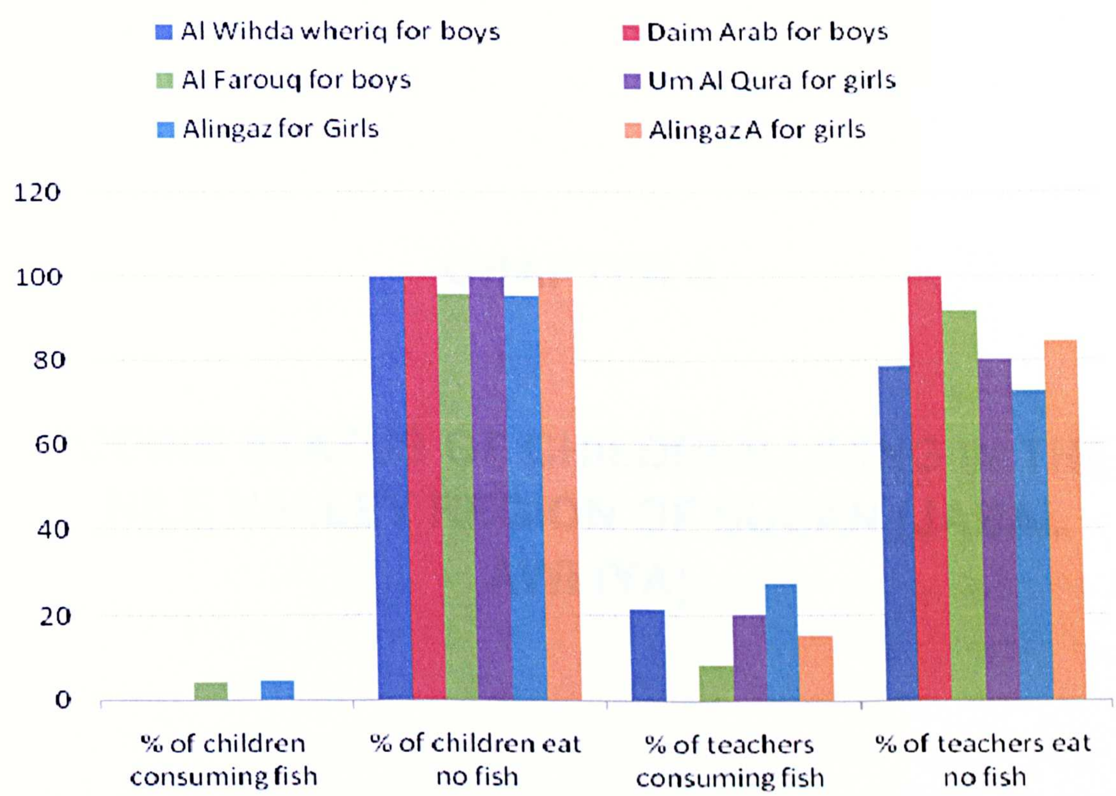
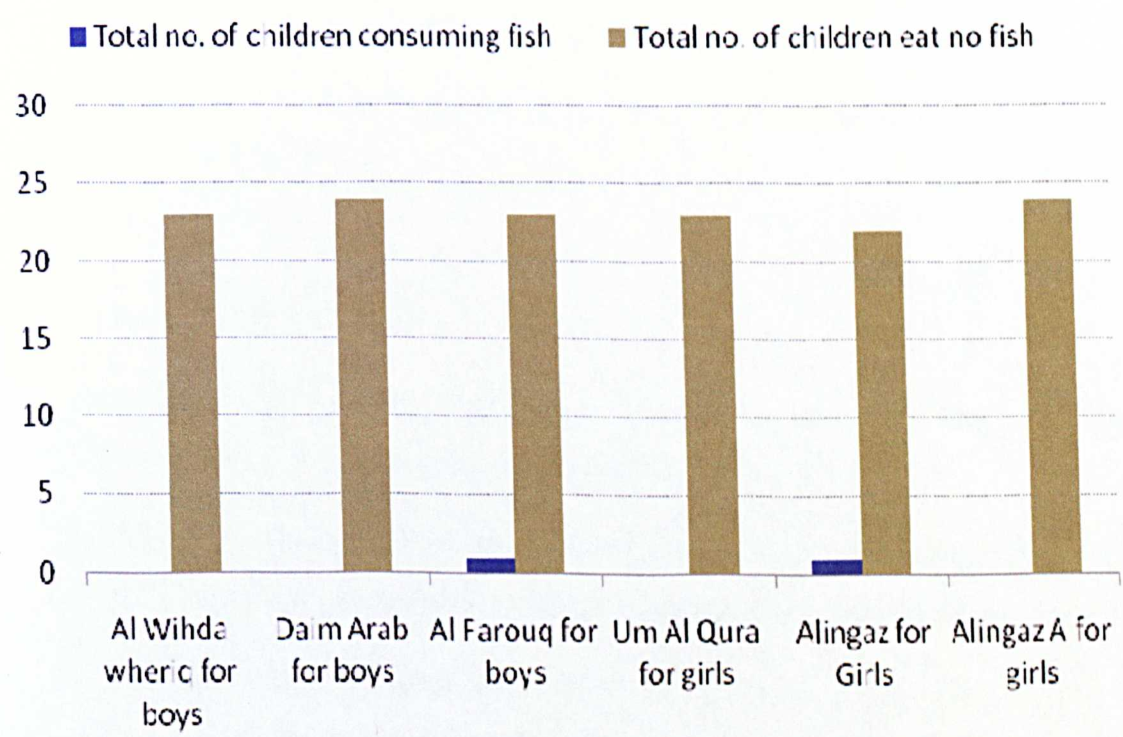


Figure 3.7. Comparison of fish intake between body and girls from Port Sudan



CHAPTER 4.

IODINE STATUS OF CHILDREN LIVING IN THE NILE VALLEY REGION OF SUDAN (JABAL AWLIYA)

4.1. THE NILE VALLEY REGION - POPULATION AND GEOGRAPHY

The Nile Valley, the most extensive oasis on earth, was created by the world's second-longest river and its seemingly inexhaustible sources. The Nile is a combination of three long rivers whose sources are in central Africa: the White Nile, the Blue Nile, and the Atbara. The British built the Jabal al Awliya Dam in 1937 to store the water of the White Nile: it is situated south of Khartoum. Much water from the reservoir has been diverted for irrigation projects in central Sudan and/or it merely evaporates, so the overall flow released downstream is not great. Except for a small area in north-eastern Sudan where wades discharge the sporadic runoff into the Red Sea or rivers from Ethiopia flow into shallow, evaporating ponds west of the Red Sea Hills. The entire country is drained by the Nile and its two main tributaries, the Blue Nile (Al Bahr al Azraq) and the White Nile (Al Bahr al Abyad). The longest river in the world, the Nile flows for 6,737 kilometres from its farthest headwaters in central Africa to the Mediterranean. The importance of the Nile has been recognized since biblical times; for centuries the river has been a lifeline for Sudan. On the other hand the Blue Nile flows out of the Ethiopian highlands to meet the White Nile at Khartoum. The White Nile flows north from central Africa, draining Lake Victoria and the highland regions of Uganda, Rwanda, and Burundi.

The location of Jabal Awliya, Nile Valley region is illustrated in the the map of Sudan in Figure 4.1.

4.2. SELECTION METHODS

This study was performed in Jabal Awliya, Nile Valley of Sudan from January 2006 to November 2006. The study expected to:

1) Determine the status of iodine nutrition of the population living in the Nile Valley, Jabal Awliya locality by measuring urinary iodine excretion.

2) Estimate the goitre prevalence in school children in the age group of 6 to 12 years by palpation.

3) Determine the iodine content in salt samples brought from home by the schoolchildren, and determine whether the iodine content of salt needs to be modified to assure adequate and safe iodine intake levels.

4) Evaluate a food frequency questionnaire to measure content of foods that routinely consumed by school children in the Nile Valley region and to investigate the geographical variation in fish consumption.

Figure 4.1. Map of Sudan and location of study area (2-Jabal Awliya)

{Source: WHO 2006}

The study protocol was designed in accordance to the WHO/UNICEF/ICCIDD, monitoring guideline (3rd edition, 2007). A probability-proportional-to-size (PPS) sampling method was used to obtain a representative sample of 140 school children aged 6 - 12 years old. A full list of all primary schools was obtained from the Ministry of Education and 6 schools (3 for boys and 3 for girls) were randomly selected.

In the first stage, six primary schools were selected (Table 4.1). In the second stage, 1 to 2 classes were randomly selected from each school depending on the number of students per class. A total of 140 children were recruited. The mean age was 9.8 years and the ratio of boy to girl was 1:1. The number of salt samples brought by the children from their homes was 120 only (20 participants did not bring salt samples for various reasons, Table 4.2).

Table 4.1. Summary information on surveyed school from Jabal Awliya

Code	School Name	No. of children surveyed	Mean age (years)
1	Al Tadreeb for boys	23	
2	Mousaab ibn Omeer for boys	24	
3	Alshahed Mousbah for boy's	24	
4	Um Ayman for girls	23	
5	Rabha Alkinaniah for girls	22	
6	Al Humaira for girls	24	
	TOTAL	140	9.8

Table 4.2. Number of salt samples collected from school in Jabal Awliya

Code	School name	Salt samples collected (*n*)
1	Al Tadreeb for boys	16
2	Mousaab ibn Omeer for boys	24
3	Alshahed Mousbah for boy's	20
4	Um Ayman for girls	20
5	Rabha Alkinaniah for girls	20
6	Al Humaira for girls	20
	Total	120

4.3. DEMOGRAPHIC QUESTIONNAIRE

Forms were designed for collecting data from the selected children and for recording lab test results. The first form was an interview questionnaire for the children's personal and socio-demographic data. Data was collected through interviews using this simple form. Apart from identification data for the child and the interviewer, the form involved questions on fish consumption and the rate. A copy of the questionnaire form is provided in Annex 2. The second form was used for recording the results of the lab tests for iodine content in urine and in salt.

A unique identifier was set for each child based on school, and the child identification number in the class listing. This composite number was printed on five sticker labels, which were used to identify each child's interview form, lab form, salt sample, and two urine samples.

The following procedures were adopted to collect data on socio-demographic, salt and urine specimen collection and thyroid gland palpation

4.4. FOOD FREQUENCY QUESTIONNAIRE

Household Knowledge, Attitude and Practice Questionnaire

- Children were trained and instructed to deliver the Questionnaire form to their parents, answer the questions and bring it back to school. This was done under the supervision of the headmaster and school health supervisor.

Salt specimen collection and testing

- Each child was asked to bring a sample of salt from home (2 tablespoons) on the day of the survey. Half of the salt that was provided for test using Rapid Test Kits (RTK).

4.5. BIOCHEMICAL AND CLINICAL METHODS

One member of each team had received training in the recognition of visible goitre by the use of palpation assessed goitre. The size and consistency of the thyroid gland are carefully noted. When necessary, the subjects are asked to swallow (e.g. some water) when being examined the thyroid moves up on swallowing. The size of each lobe of the thyroid is compared to the size of the tip (terminal phalanx) of the thumb of the subject being examined.

A sample of urine was collected from every child and divided into two aliquots: Sample 1 and Sample 2. A urine sample was first collected from every child in a sterile pre-labelled capped cup. With a disposable pipette, the lab technician transferred at least 5 ml of urine to each of the two pre-labelled vials and screwed the caps on tightly. Urine samples were shipped to the Medical Research Centre (MRC), in Cape Town, South Africa (International Laboratory Network for Iodine) where the urine samples were tested for urinary iodine content using the ammonium persulfate method. Quality control was provided by MRC, according to the WHO/UNICEF/ICCIDD approved protocols.

4.6. CAPACITY BUILDING

A three-day training workshop was conducted in preparation of the survey in Jabal Awliya. The training programme included introduction of iodine deficiency disorders control program, the survey methodology and the using indicators of the assessment (Tables 2.1, 2.2, 2.3, 2.4, 2.5). The participants were also trained on collection of urine and salt samples, use of rapid test kits, and assessment of goitre by palpation.

4.7. QUALITY CONTROL

For quality control and verification, a field, office and lab quality control procedures were followed at the various stages of the study. For field quality control: a citizen and a focal point from the Federal Ministry of Health were assigned for each school. They were responsible for checking the completion, accuracy and consistency of the forms, and for checking the labelling and suitability of salt and urine samples.

Lab quality control: All instructions by the Medical Research Centre laboratory in Cape Town (affiliated lab to International Iodine Network Laboratories). All samples were kept in the specially provided refrigerator and transported following carefully the guidelines of WHO and the DHL.

Data were cleaned upon completion of data entry. This involved creating summary tables with minimum and maximum values, frequencies and cross-tabulation. In the event that any outlying values were detected, they were ascertained from the original forms.

4.8. STATISTICAL ANALYSIS

Data are presented using descriptive statistics in the form of frequencies and percentages for qualitative variables and means, medians and standard deviations for quantitative variables. Tabular and graphic presentations were used as appropriate.

To calculate descriptive analyses, we entered the set of data we obtained in the data editor. Once the data are in data editor, we were able to calculate, for each group, the mean, and standard deviation, minimum, and maximum, variance, range, and skewness of each group. T-test was used to compare qualitative variables.

The data are presented as mean ± standard deviation (SD). All data analyses were performed with statistical package SPSS for windows (version 13).

4.9. RESULTS

4.9.1. Urinary Iodine Concentration

The median urinary iodine of the study sample in Jabal Awliya was 159.6 µg/L, and the mean urinary iodine was 178.1 ± 109.7 µg/L showing optimum (or adequate) intake of iodine, according to the criteria for assessing iodine nutrition based on median urinary iodine concentrations in school children. The urinary iodine concentration of children is provided in Annex 2.

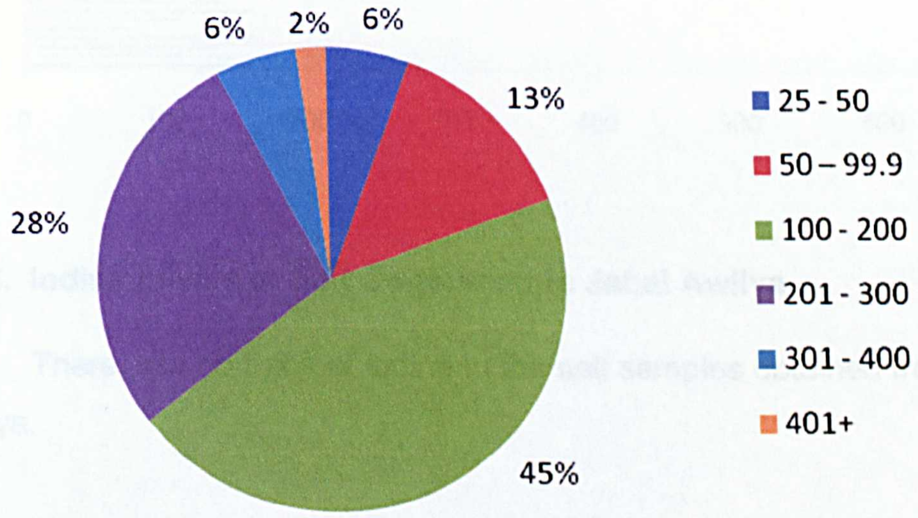
The mean urinary iodine concentrations of children from six schools are provided in Table 4.3. Of the six school, the urinary iodine level of school girls from Um Ayman for Girls was lowest and significantly differ from that of boys from Moussab ibn Omeer for Boys ($p<0.0001$).

As shown in Figure 4.2, 45 % of the studied samples had iodine concentration between 100-200 µg/L (adequate), and 28% had iodine concentration between 200 – 300 µg/L, and 13 had iodine concentration less than 100 µg/L. Only 2 % of samples exceeded 400 µg/L. The minimum level was 31.2 µg/L and the highest urinary iodine level was 665.1 µg/L, with a range of 633.4 µg/L. The result clearly shows the optimum intake of iodine by the population living in Jabal Awliya (Nile Valley).

Table 4.3. Urinary iodine concentration (UIC) of children from six schools in Jabal Awliya (mean ± SD μg/L)

Code	School Name	UIC (μg/L)
1	Al Tadreeb for boys	185.5 ± 136.0
2	Mousaab ibn Omeer for boys	173.3 ± 98.1
3	Alshahed Mousbah for boy's	249.1 ± 123.7
4	Um Ayman for girls	99.4 ± 61.1
5	Rabha Alkinaniah for girls	179.2 ± 86.4
6	Al Humaira for girls	179.2 ± 86.4
	TOTAL	178.1 ± 109.7

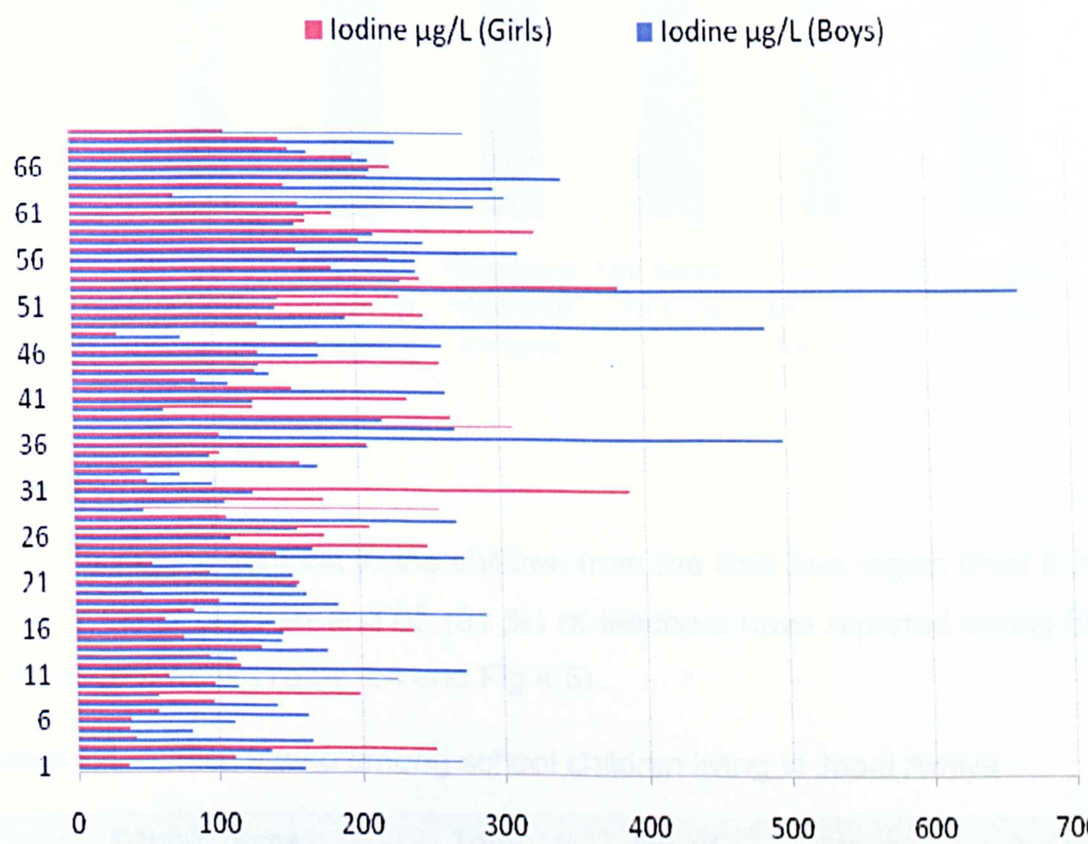
Figure 4.2. Distribution of the urinary iodine (μg/L) in the samples from Jabal Awliya according to the WHO criteria



4.9.2. Urinary iodine Concentration by Gender

Similar to the children from Port Sudan, boys had higher urinary iodine than girls (Fig 4.3). The mean urinary iodine concentration for boys and girls were 195.9 ± 104.1 μg/L and 155.8 ± 83.1 μg/L, respectively.

Figure 4.3. Distribution of urinary iodine concentration by gender



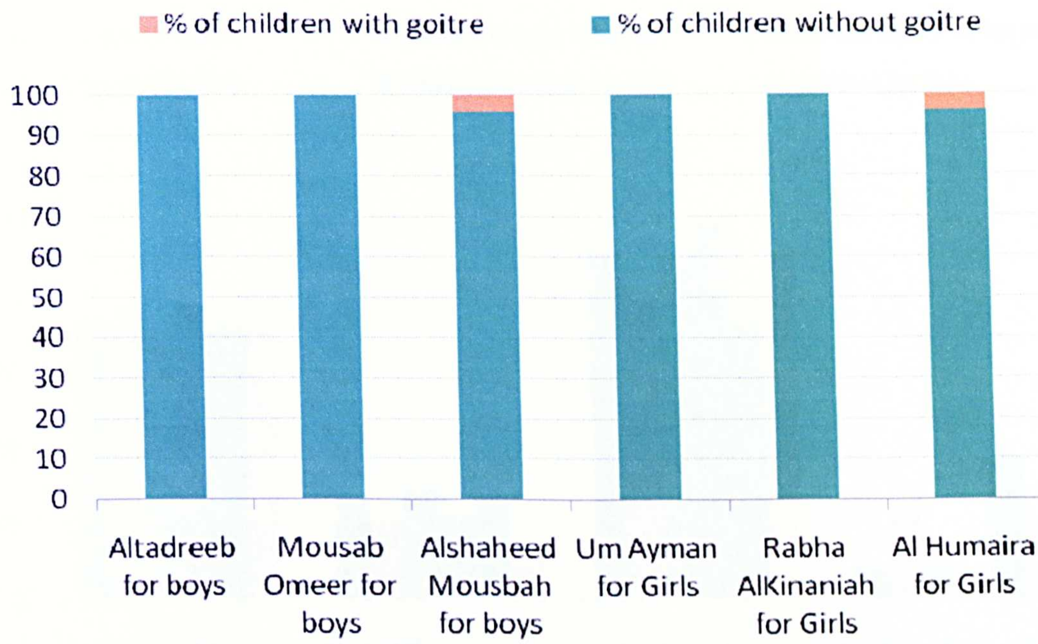
4.9.3. Iodine Levels in Salt Consumed in Jabal Awliya

There was no trace of iodine in the salt samples obtained from Jabal Awliya.

4.9.4. Goitre Rate

Of the 140 school children from Jabal Awliya, only 1.4 % (2 children) of them presented with goitre (Fig 4.4).

Figure 4.4. Goitre rate (%) among school children from Jabal Awliya



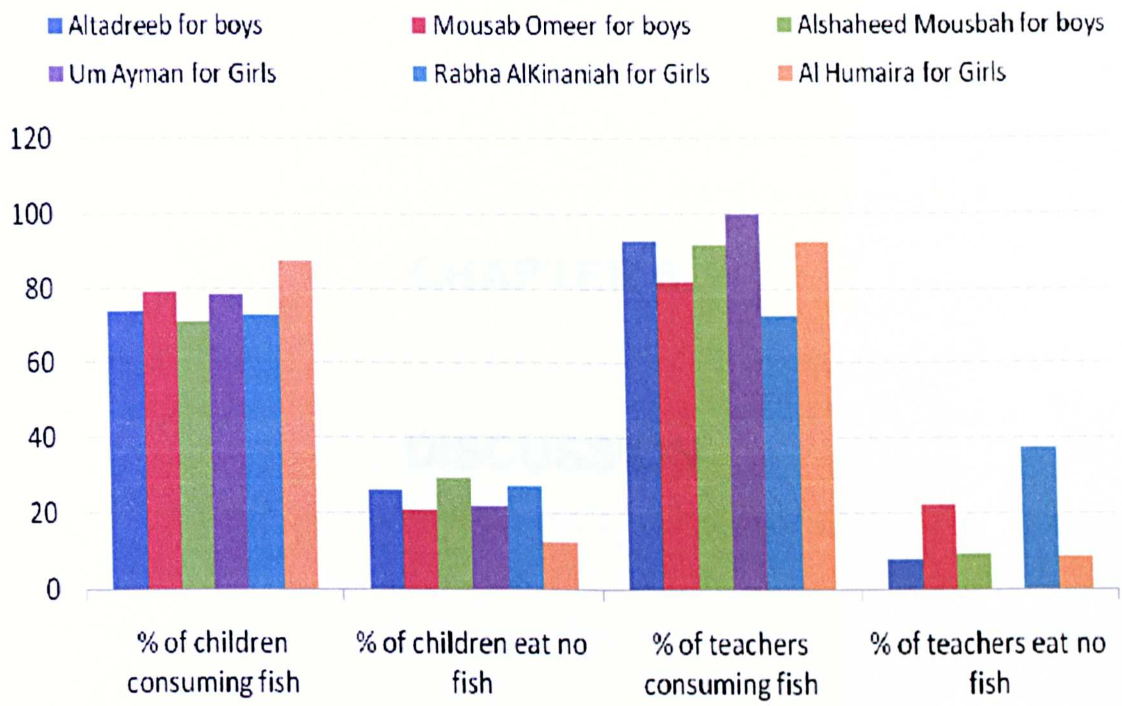
4.9.5. Fish Intake

In striking contrast to the children from the Red Sea region (Port Sudan), 108 (77 %) of children and 65 (91 %) of teachers have reported eating fish at least once a week (Table 4.4 and Fig 4.5).

Table 4.4. Fish intake among school children living in Jabal Awliya

Code	School name	Total children interviewed	No. of children consuming fish	No. of teachers interviewed	No. of teachers consuming fish
1	Al Tadreeb for boys	23	17	14	13
2	Mousaab ibn Omeer for boys	24	19	11	9
3	Alshahed Mousbah for boy's	24	17	12	11
4	Um Ayman for girls	23	18	10	10
5	Rabha Alkinaniah for girls	22	16	11	8
6	Al Humaira for girls	24	21	13	12
	TOTAL	140	108	71	63

Figure 4.5. Percentage of fish intake among school children and teachers from Jabal Awliya



CHAPTER 5.

DISCUSSION

5.1. THE STATUS OF DOMESTIC IODISATION CAPACITY

The iodine deficiency disorders problem in Sudan is widespread and severe, particularly in the mountainous states of Darfur and Blue Nile State where goiter rates are as high as 87% and 75% respectively (Eltom 2001). According to the report issued in 1997 by the Federal Ministry of Health in Sudan, 242,400 Sudanese children are born unprotected from iodine deficiency consequences each year. Among this group, 7,000 may develop cretins (3 %), 24,000 may suffer from severe mental retardation (10 %) and 210,000 newborns may grow up mildly intellectually deficient (87 %). According to the last survey, the prevalence of goitre in Sudan was 22 % (Federal Ministry of Health Sudan 2000). On the basis of this figure, it is anticipated that the productivity of affected people is reduced by 5 – 25 %.

Sudan like many other developing countries has a long history of Iodine deficiency. Endemic goitre in Sudan was first reported in 1952 in a small area inhibited by A'zande in Southwest Sudan near the border with Zaire and in other neighbouring areas (Kambal 1969). In the Darfur region of Sudan, 85.5 % of 7,134 subjects examined had goitre, with school children being most affected (Eltom 1984).

The prevalence reaches 40% in some regions of the country (Federal Ministry of Health Sudan 2000). A comprehensive iodine deficiency disorders national survey conducted by the Federal Ministry of Health Sudan revealed that the prevalence in Port Sudan, Red Sea State of Eastern Sudan and in the Nile valley Jabal Awliya, at 8.2 % and 5.4 % respectively (Federal Ministry of Health Sudan 2000).

World Food Programme and FAO estimated that 3.6 million inhabitants from both of above regions were in need of food assistance, with internally displaced people, refugees and returnees particularly exposed to food insecurity and health problems (FAO 2005). The Red Sea region is particularly affected by chronic underdevelopment, widespread poverty and marginalization of large strata of the population.

The result of the findings of the survey conducted by the Federal Ministry of Health in Sudan (2000) has showed that the prevalence rate at 5 - 8 % in Khartoum and Port Sudan respectively. It was surprising this is not reflecting the actual prevailing status as it is known that the household consumption of iodised salt in both regions is very poor - less than 11 % (Federal Ministry of Health Sudan 2000) and that more than 90 % of the population in both regions suffers from poverty and food insecurity (Bottigliero 2002).

To verify the above findings, we have collected and assessed the Iodine nutrition status of school age children from the Red Sea State of Eastern Sudan (Port Sudan), and the status of the children from Jabal Awliya in the Nile valley region of the Sudan, through collection and assessment of salt and urine samples and palpation of the goiter, following the Assessment of Iodine Deficiency Disorders and Monitoring their Elimination: Guidelines: 2nd and 3rd edition, 2007.

Sudan adopted universal salt iodisation as a national iodine deficiency disorders prevention strategy in 1994; ministerial decrees issued at the time required all edible salt to be iodised to a level of 50 ppm using KIO_3. Several amendments have been issued since but not enforced. A Ministerial Declaration (No.13/2003) issued on the 7th July 2003 under the Public Health Law of 1975, provided for blending of salt with potassium iodate 30 mg/kg (Federal Ministry of Health Sudan 2000). In spite of the fact that Sudan adopted salt iodisation as the strategy for the elimination of iodine deficiency disorders as early as in 1994, it is evident that there is hardly any progress in the implementation of the strategy.

The iodine level in salt samples collected from the Red Sea region was excessively higher (140-361 mg/kg) compared with the recommended values by WHO/ICCIDD (15 - 40 mg/kg) (WHO/ICCIDD 2007). The level of iodine in salt, even in a tropical country like Sudan, should not exceed the recommended level. There should be a monitoring mechanism in place to monitor the iodine content of all types of salt intended for human consumption, if not all the constituents of the salt.

According to the demographic household survey carried out in 2005 by Department of Health Sudan (Federal Ministry of Health Sudan 2005) and UNICEF report (2006), an estimated number of less than 11% of Sudanese households has access to iodised salt, a figure which is far below that for the sub-Saharan region (66 %). Despite these gloomy facts on the availability of adequately iodised salt in ample quantity, the iodine content of salt consumed by the schools in the Red Sea exceeded the normal recommended values (20 – 40 mg/kg) by more than 9 %.

Following countrywide iodisation measures in China in 1996, levels of iodine intake varied among regions. Iodine intake was mildly deficient in the Panshan region (median urinary iodine excretion >200 µg/L), more than adequate in the Zhangwu region (median urinary iodine excretion, 200 - 299 µg/L) and excessive in the Huanghua region (median urinary iodine excretion, >300 µg/L). The authors noted increasing thyroid disorders during this time (Teng 2006).

The effect of the consumption of additional iodine is also dependant on the initial status of the population. In populations that are mildly deficient or replete, increases in dietary iodine may induce hypothyroidism, while in populations that were previously severely deficient, increased dietary iodine is associated with hyperthyroidism (Markou 2001).

Iodine-induced hyperthyroidism is a serious condition that may in extreme cases lead to death, usually from heart-associated causes (Dunn 1998). The increased susceptibility of iodine-deficient populations to IIH, results mainly from pre-existing multi-nodal thyroid disease and the presence of autonomous tissue in the thyroid gland (Corvilian 1998). Previous studies have shown that IIH can occur following the introduction of iodised salt and suggest that the risk of this adverse affect is related to the level of intake, although it is limited to a relatively short period of time after introduction (Gomo 1999). Populations whose diet was deficient in iodine previously are particularly at risk of developing IIH if levels of intake are excessive. Optimal iodine intake is therefore important, but due to poor quality control at the production level and the high undesired fluctuation levels of fortification, which sometimes are up to several times higher than the WHO recommendation, there is now a risk that populations, who were severely deficient in iodine previously, are now consuming an excess. Although it is accepted that the risks posed by deficiency greatly outweigh those associated with excess, it is still a concern that avoidable morbidity and mortality may occur as a result (Delange 2001). Under reporting of IIH is very likely in developing countries where health.services may be poorly developed and there is coexistence of predisposing iodine deficiency.

5.2. ALTERNATIVE SOURCES OF IODINE

According to the findings of this study, the median urinary iodine was lower in the Nile valley region (159.66 ug/l) with low iodine content in salt (below detection limit) compared to the levels in the Red Sea region (555.15 ug/l, excessive) with high content of iodine in salt (140 - 360 mg/kg). The fact that school children in the Nile Valley have significantly lower urinary iodine level despite low iodine content in salt suggests that that there are other sources of iodine in this region. The iodine could have come from fish as 91 % of children in the Nile Valley have reported eating fish frequently. In contrast, only 1.7 % of children in the Rea Sea have reported consuming fish.

A study in Istanbul, Turkey showed that although the use of iodised salt was low (44.4 %), the median urinary iodine level was in the normal range (105 μg/L) (Gür 2003). The study concluded that the iodine deficiency rate was not influenced by the use of iodised salt and attributed to other sources such as fish and/or the iodine in the soil and water. However, the findings from an epidemiological study to determine the prevalence of iodine deficiency disorders among primary school conducted in Upper Egypt which environment is similar to the Red Sea suggest that the iodine content of soil and drinking water samples was considered low (El-Sayed 1995).

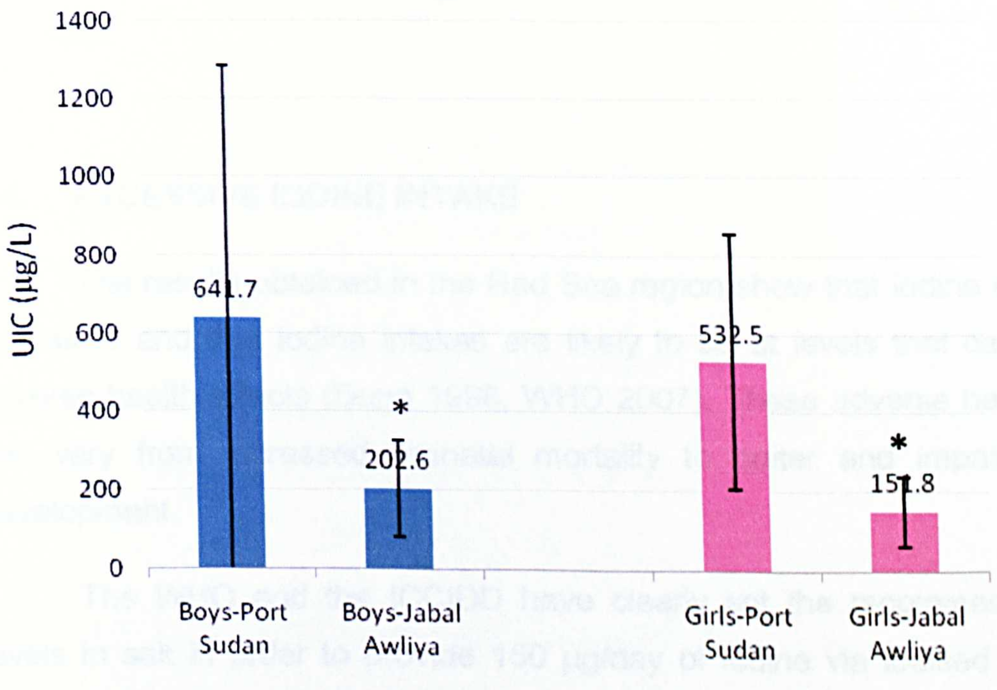
5.3. URINARY IODINE CONCENTRATION

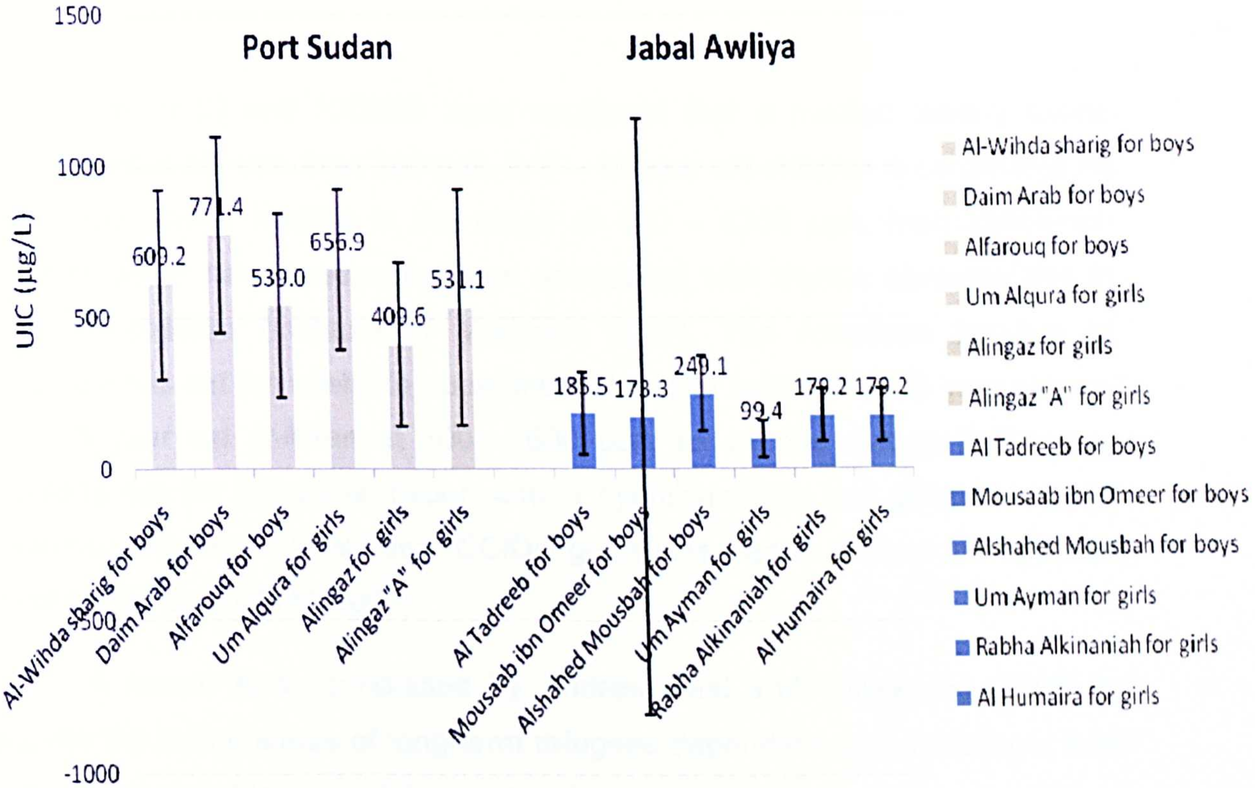
According to WHO/UNICEF/ICCIDD, Assessment of Iodine Deficiency Disorders and Monitoring their Elimination (3rd edition 2007), criteria for tracking progress of iodine deficiency disorders elimination, urinary iodine concentration levels less than 100 µg/L in a population should not exceed 50%, and for urinary iodine concentration levels less than 50 µg/L the proportion of the population should not exceed 20 %. However, the result we obtained in this study has shown the minimum urinary concentration level at 38 µg/L and the highest at 1470 µg/L. This draws the attention to the fact that the consumption of iodised salt is more than adequate (20 - 40 mg/kg). Conversely the results from the Nile Valley region (Jabal Awliya) indicate optimum (or adequate) intake of iodine, according to the criteria for assessing iodine nutrition based on median urinary iodine concentrations in school children. The minimum level of urinary iodine concentration was 31.3 µg/L and the highest was 665.2 µg/L, with a range of 633.4 µg/L. Urinary iodine concentration was found adequate (100 - 200 µg/L) in 45 % of the study group, and more than adequate (200 - 300 µg/L) in 27 %, and excessive (above 300 µg/L) in only 8% of the study sample. The result obtained in this region indicates that population intake of iodine nutrition is within the required levels. Although the salt samples collected from schools contained no iodine, but the adequate intake was a result of regular intake of fish by the population (77 % of population consume fish at least one time a week).

In the Red Sea region, urinary iodine concentration exceeded 200 µg/L in more than 92 % of the children. Only about 6 % of the studied samples showed an adequate intake (100 - 200 µg/L). Moreover, 92 % of the studied samples had iodine concentration more than adequate (16 %), had iodine concentration between 200 - 300 µg/L, and 18% between 300 – 400 µg/L, and 58 % had above 400 µg/L, showing excessive intake of Iodine nutrition. As shown in Figure 5.1, the urinary iodine concentration was strikingly higher in children from Port Sudan compared with the children from Jabal Awliya.

We have speculated the cause of this high urinary iodine concentration likely to be dietary intake from salt based on the measurement of salt samples. The estimated amount of iodine in salt is about 9 times of the WHO safe level of intake (20 - 40 mg/kg), and led to urine excretion levels in excess of the upper recommended median limit (200 µg/L). The result also calls for particular care to be paid to optimise the level of iodine consumption to minimize risks of both inadequate and excessive intake of iodine

Figure 5.1. Comparison of urinary iodine concentration of boys and girls from Port Sudan and Jabal awliya (mean ± SD)





5.4. EXCESSIVE IODINE INTAKE

The results obtained in the Red Sea region show that iodine excretion is excessive and that iodine intakes are likely to be at levels that carry risks of adverse health effects (Dunn 1998, WHO 2007). These adverse health effects can vary from increased prenatal mortality to goiter and impaired mental development.

The WHO and the ICCIDD have clearly set the recommended iodine levels in salt in order to provide 150 µg/day of iodine via iodised salt. Iodine concentration in salt at the point of production should be within a range of 20 – 40 mg of iodine (34 – 66 mg potassium iodate) per kg of salt. However, the lower limit of 20 mg/kg of salt is recommended in case all of the salt that is being used in processed food has been iodised. Under these circumstances, median urinary iodine levels will vary from 100 – 200 µg/l (WHO 1996). School children in the Red Sea (Port Sudan) consume excessive iodine through excessively iodised salt that are unnecessarily high.

The WHO and ICCIDD have cautioned that a median urinary iodine concentration of more than 300 µg/L in 6 – 12 year old children is considered as excessive. Iodine intakes in the range of 400 – 1300 µg/L from iodine-rich drinking water have previously been associated with thyroid abnormalities in Chinese children (Institute of Medicine 2001). The American Institute of Medicine has set the tolerable upper intake level for iodine in 4 – 8 year old and 9 – 13 year old children at 300 – 600 µg/L as excess dietary iodine may increase risk for thyroiditis, hyper- and/or hypothyroidism and goiter (Li 1987). However, the recent WHO and ICCIDD guidelines clearly defined the optimum level at 200 µg/L (WHO 2007).

A recent study conducted by Andrew Seal and colleagues (2005) to assess the iodine status of long-term refugees dependent on international food aid and humanitarian assistance concluded that excessive consumption of iodine is occurring in most of the surveyed populations in Darfur refugee camp in the western of Sudan due to intake of high iodine content in salt. At present, the Sudanese government has set the specification for iodine content of salt at 25 – 35 mg of iodine per kg of salt.

It is therefore concluded that iodine excretion is excessive in Red Sea State of Eastern Sudan and that iodine nutrition intake is likely to be at levels that carry risks of adverse health effect (Delange 2001).

5.5. IMPACT ON DEVELOPMENT AND HEALTH

Some progress has been made in several countries since the international efforts to eliminate iodine deficiency disorders have been initiated, however there is no supportive policy environment yet for successful universal salt iodisation in Sudan. In the absence of a monitoring and surveillance system, the population will be exposed to suffer from the double burden of both iodine deficiency and excessive iodine intake. The monitoring and surveillance of iodine level by measuring the urinary iodine concentration is vital to guide the whole iodine deficiency disorders control programme operation.

CHAPTER 6.

CONCLUSION AND RECOMMENDATIONS

Previously deficient populations are particularly at risk of developing iodine induced hyperthyroidism if levels of intake are excessive. Optimal iodine intake is therefore important, but due to poor quality control at the production level and the high levels of fortification required by some governments' legislation, which specifies up to 2.5 times of the WHO recommendation, there is now a risk that populations which were previously severely deficient in iodine are now consuming an excess.

Finally, based on the results of this study, it is concluded that both inadequate and high intakes of iodine exist in Sudan which will cause negative impact on health and economy due to the high cost involved in treatment of the consequences resulting from both high and low intake of iodine.

The results that we report here on excessive iodine intakes should in no way be taken to lessen the essential work in the eradication of iodine deficiency wherever it occurs. Nonetheless, people should be aware of the danger of excess iodine intake and ensure that adequate monitoring is in place. For Sudan, it would be appropriate to obtain more extensive baseline data on the prevalence, geographic distribution, knowledge, attitudes and practices relating to iodine deficiency and its elimination. The aim should be to provide a strategy that ensures optimal control of iodine supplementation levels to those in need, together with effective monitoring for efficacy and safety.

The Sudan government and developing agencies need:

- To conduct a nation-wide public health education program to promote community awareness of the importance of the use of iodised salt and the hazardous effects of inappropriate iodine intake. This should be directed mainly at the rural community and achieved through educational and social marketing campaigns.
- To introduce iodine deficiency control and prevention in education curricula at all levels.

- To introduce proper monitoring systems for the salt iodisation program. The systems should have a systematic approach for supervision and regular monitoring of salt at production sites, retail shops and households and at the schools level.
- To encourage research institutions to study the pattern of iodised salt and the impact of food rich in iodine in population.
- To encourage rectifying the environment by spraying and or injecting iodine into the soil.

We conclude that although iodine supplementation should be implemented to prevent and treat iodine-deficiency disorders, supplementation should be maintained at a safe level. Levels that are more than adequate (median urinary iodine excretion, 200 to 299 µg/L) or excessive (median urinary iodine excretion, >300 µg/L) is not safe, especially for susceptible populations with either potential autoimmune thyroid diseases or iodine deficiency. Supplementation programs should be tailored to the particular region. No iodine supplementation should be provided for regions in which iodine intake is sufficient, whereas salt in regions in which iodine intake is deficient should be supplemented with iodine according to the degree of iodine deficiency.

Therefore, there is an urgent need for a regulatory mechanism during the process of iodine fortification, and at the point of entry of imported and donated iodised salt, as well as the mode of delivery. We recommend that independent professionals should critically evaluate the health impact of the excessive consumption of the nutrient in Port Sudan, and the Red Sea State of Eastern Sudan.

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ANNEXES

Annex 1. **List of schools in Red Sea region**

Administration Unit	Name of School	Number of Students		
		Boys	Girls	Total
North Tokar	1. Um Almuminen	0	315	315
	2. Alhumira	0	312	312
	3. Aldelta	0	385	385
	4. Bent Wahab	219	69	288
	5. Alzhra	103	.51	154
	6. Khadiga bent Khuild	0	59	59
	7. Amar Ibn Yassir	404	0	404
	8. Aby Baker Alsedeg	425	0	425
	9. Alfaroug	409	0	409
	10. Musab Ibn Aumair	196	0	196
	11. Alkhaleel	370	0	370
	12. Ali Ibn Aby Taleb	140	26	166
	13. Airam	142	47	189
	14. Dhant	60	17	77
	15. Ashat Boys	118	0	118
	16. Ashat Girls	0	65	65
	17. Setrab Boys	50	0	50
	18. Tokar Secondary	0	67	67
	Sub-Total (18 schools)	2,636	1,413	4,049
South Tokar (Akiek)	1. Marafeet Boys	270	0	270
	2. Marafeet Girls	0	121	121
	3. Andal Co.educ.	90	71	161
	4. Durhaab Co.	97	64	161
	5. Adobana Co. educ.	59	41	100
	6. Agetay (A)	121	40	161
	7. Agetay (B)	90	77	167
	Sub-Total (7 schools)	727	414	1141
South Tokar (Garora)	1. Garora Co.educ.	278	127	405
	2. Aitarba Co.educ.	148	67	215
	3. Kuna(NEW)	35	15	50
	4. Agiek	71	20	91
	5. Garora Alteknilia	100	42	142
	Sub-Total (5 schools)	632	271	903
Rural Tokar	1. Osor Boys	133	0	133
	2. Osor Girls	0	87	87
	3. Dulabyai Boys	121	0	121
	4. Dulabyai Girls	0	49	49
	5. Denwier	85	0	85
	6. Odwan	115	0	115
	7. Farek Slaeb	104	0	104
	8. Batab	80	0	80
	9. Gabayab	51	29	80
	10. Harbagad	50	0	50
	11. Waram (NEW)	117	0	117

	12. Seghaeb (NEW)	50	0	50
	Sub-Total (12 schools)	906	165	1,071
Jabeit El Maadin	1. Ali Ibn Abi Talib	90	18	108
	2. Oko	50	21	71
	3. Tumundura	100	12	112
	4. Noraiet	51	20	71
	5. Dururba	30	11	41
	6. Yomomt	54	14	68
	7. Sodi	60	10	70
	8. Elhufra	50	20	70
	9. SufaYia	40	6	46
	10. Kamoreib	24	17	41
	11. Kamoreib-A	30	13	43
	Sub-Total (11 schools)	579	162	741
Osief	1. Abu baker Alsedeg	175	77	252
	2. Osief Co.	277	105	382
	3. Gabteet	90	24	114
	4. Eise	40	14	54
	5. Maroub	46	16	62
	6. Osief Sec.	0	25	25
	Sub-Total (6 schools)	628	261	889
Mohamed Goal	1. M. Goal	143	33	176
	2. Dungonab	79	18	97
	3. Eit	60	37	97
	4. Salalasair	45	20	65
	5. Eirkiay	47	18	65
	6. Harnkook	50	17	67
	7. Shenab	40	16	56
	Sub-Total (7 schools)	464	159	623
Al-Gunub	1. Saloom	137	43	180
	2. Tomalah Girls	0	101	101
	3. Tomalah Boys	233	0	233
	4. saloom girls	0	41	41
	5. Kessebyay	47	64	111
	6. Masjid Kazem	74	76	150
	7. Komossana	44	22	66
	8. Arbbat Alkharbeia	41	19	60
	9. Shandoday	44	5	49
	10. Tomly	47	48	95
	11. Salatieb	57	11	68
	12. Togalhoosh	63	11	74
	13. Kloleet	27	24	51
	14. Asotriba	44	44	88
	15. Hanoyeet	50	38	88
	16. Gbaidieb	59	0	59
	17. Aubo	20	19	39
	18. Okogaramaiet	32	18	50
	19. Rubaieet	45	45	90
	20. Mohd. Ali Kir	311	164	475
	21. Korwieb	73	23	96

	22. Sorbiyiet	50	0	50
	23. Toksar	43	26	69
	24. Tarsaey	75	0	75
	25. Mohd. Tahariet	30	20	50
	26. Sabatiem	47	14	61
	27. Saloom secondary	0	35	35
	Sub-Total (27 schools)	1,693	911	2,604
Al-Awlieb	1. Kolkoy	52	38	90
	2. Mustahleil	90	84	174
	3. Birajam	94	81	175
	4. Hoshieeb	93	28	121
	5. Shalhoot	72	0	72
	6. Rahoda	45	52	97
	7. Dadat	55	34	89
	8. Togailo	49	21	70
	9. Tober	25	28	53
	10. Walout	50	0	50
	11. Edabay	37	52	89
	12. Agwamtsarara	78	37	115
	13. Sandal	25	25	50
	14. Amoursarara	28	30	58
	15. Sararawario	50	0	50
	16. Gasheet	35	.25	60
	17. Musayaet Co.	33	25	58
	Sub-Total (17 schools)	911	560	1,471
Sinkat	1. Moh.Elamin	235	0	235
	2. Jelany Moh	315	0	315
	3. OsmanDegna	400	0	400
	4. Alshref Almlak	450	0	450
	5. Airkwit Boys	300	0	300
	6. Alshrefa Marium	0	400	400
	7. Osman Belea	0	300	300
	8. Ingaz	0	150	150
	9. Airkwit Girls	0	180	180
	10. Almarkz Alrefe	105	95	200
	11. Samat Co.	100	50	150
	12. Halgeet Co.	80	50	130
	13. Shadaweet Co.	40	30	70
	14. Shakan Co. educ.	42	.18	60
	15. Nassait Co educ.	40	20	60
	16. Bramio Co. educ.	50	30	80
	17. Bir anfi co educ.	57	28	85
	18. Esaf Co.	55	25	80
	19. Eritrie Co.	35	25	60
	20. Baksha Co.	40	20	60
	21. Edhanun Co.	45	15	60
	Sub-Total (21 schools)	2,389	1,436	3,825
Jebeit	1. Salh Shoof	228	0	228
	2. Ohaj Ismail	198	0	198
	3. Omer Abu Amna	314	0	314

	4. Osman El sayed	140	110	250
	5. Oudrous Boys	95	35	130
	6. A/Rahim Badery	0	292	292
	7. Alsharefa marium	0	59	59
	8. Abu fatma Osman	177	140	317
	9. Almushah	38	17	55
	10. Taha Husean	0	325	325
	11. Khadiga bent khuild	38	13	51
	Sub-Total (11 schools)	1,228	991	2,219
Dordeib	1. Alshargia	486	0	486
	2. Alshargia	0	477	477
	3. Umalgura	137	98	235
	4. Delay Co.	99	69	168
	5. Alkharbeia Co	29	21	50
	6. Alshemalia	0	130	130
	7. Genytoa Co.	31	19	50
	8. Almanar	82	0	82
	9. Adarot	95	0	95
	10. Khour Duedieb	55	60	115
	11. Andraif Co.	45	35	80
	12. Al ghabash Co.	44	22	66
	13. Tomliet Co.	35	21	56
	14. Fadagragat Co.	29	28	57
	15. Lasoub Co.	37	13	50
	16. Fafiet Co.	41	18	59
	Sub-Total (16 schools)	1,245	1,011	2,256
Haya	1. Hayia Alshargeia	350	0	350
	2. Hayia Alshargeia	0	280	280
	3. Hayia Alkharbeia	0	280	280
	4. Hayia Alkharbeia	350	0	350
	5. Shediab	187	93	280
	6. Musmar Co	70	60	130
	7. Tolagrieb	175	105	280
	8. Elkilo	85	65	150
	9. Elrojal Co	50	0	50
	10. Inha	55	25	80
	11. Hamaset	50	0	50
	12. Ekidi	30	20	50
	Sub-Total (12 schools)	1,402	928	2,330
Tahamiam	1. Tahamiam	245	0	245
	2. Tahmiam	0	164	164
	3. Sangany	90	44	134
	4. Amrien	65	0	65
	5. Gabteet	56	0	56
	6. Yoymalal	90	0	90
	7. Telco	114	50	164
	8. Kabashi Isa secondary	0	63	63
	Sub-Total (8 schools)	660	321	981
TOTAL		16,100	9,003	25,103

Annex 2. Quëstionnaire form إضرابات نقص اليود بالسودان

Identification data (Section I)			المعلومات الديموغرافية و التعريفية Demographic data
بيانات الباحث		Researcher:	
مسلسل code	الأسئلة ومحدداتها Questionnaires	الاجابة Answers	الرمز Code
I 1	اسم جامع البيانات Data collector name	....	
I 2	اسم المشرف (مراجع) البيانات Supervisor name	....	
I 3	تاريخ جمع البيانات Date	...../..../....	
I 4	رقم التلميذ في العينة Pupil Number	....	
			بيانات التلميذ الاساسية Basic data of the child (Pupil)
I 5	اسم المحلية The locality	....	
I 6	اسم المدرسة Name of the school	....	
I 7	الفصل الدراسي class	....	
I 8	الجنس (النوع) Gender-sex	1. ذكر 2. أنثى Male - female	
I 9	العمر بالسنوات سنة Age	....	
I 10	عدد أفراد الأسرة Number of the family members	....	
I 11	مهنة الاب Profession of the father	....	
I 12	اسم التلميذ Name of the pupil	....	

الغذاء Diet (Section D)			
م	Questions الأسئلة ومحدداتها	الإجابة (Answer Y- N)	الترميز Code
D 1	خلال أيامكم العادية، هل تتناولون السمك في إفطاركم Do you take fish in Breakfast/		
D 2	خلال أيامكم العادية، هل تتناولون السمك خلال وجبة الغذاء . Do you take fish during lunch		
D 3	خلال أيامكم العادية، هل تتناولون السمك خلال وجبة العشاء Don you take fish during dinner		
D 4	خلال الأسبوع الماضي، كم مرة تناولتم فيه الأسماك؟ How many times you had fish in your diet during the last week	عدد المرات	
المعرفة knowledge (Section K)			
K 1	هل سمعت من قبل عن عنصر اليود؟ (اذا لا انتقل الي K3): Did you ever hear about Iodine	1. نعم 2. لا 3. لا اعرف	

ANNEX 3.

Guidelines on handling of samples by International Council for the Control of Iodine Deficiency Disorders

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The following guidelines on collection and handling the samples are appropriate:

1. Review the Survey Form that should be prepared by education officials beforehand. The form should have names, age (or date of birth) and sex of all children who were randomly selected to participate in the survey. Check that all children have provided sample of salt in sealed plastic bag and Informed Consent Statement signed by parents or legal guardian.

2. Write a number assigned to each child in the Survey Form for the cluster on his or her wrist with permanent marker or pen so that the child would not forget or change it.

3. Write a number on each sealed bag with salt brought by children from their homes. The number on child's wrist should be corresponding to number of the bag.

4. Number all cups for collection of urine before distributing them to schoolchildren. Give each child an individual cup with number that is corresponding to number on child's wrist. Instruct him or her to go into the bathroom and urinate directly into the cup. Inform the children that they do not need to fill up the cup, but to fill it approximately half full. It is important to ensure supervision of children to make sure they do not share urine specimens or add other fluids to the sample. Some participants made need time to produce a urine specimen and some may not be even able to produce a specimen during the survey.

5. When the child returns with urine sample, verify the participants individual number on the Survey Form with number on his or her wrist and with

number on the cup. Put all cups with urine on table and cover them with screw cap.

6. When collection of urine and salt samples is complete:

- Test the salt for the presence of iodine. Take small amount of salt (half tea spoon) from each bag with salt. Put it on a piece of white paper. Using the rapid salt test kit (RTK), place 2-3 drops of testing solution on the salt sample. If there is no colour change, then record "0" as this reflects the fact that there is no iodine in the salt. If the salt turns blue or purple, then record the number "1". Record data for all selected samples using the Survey Form.
- Make note of the type of salt that is tested: mark coarse salt as "1" and fine salt as "2" in the Survey Form. Record "0" if it is not possible to distinguish type of salt.
- Select 15 urine cups from 30 samples collected from children. For uniformity of data collection, select samples with odd numbers (1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, and 29). Mark this numbers on the Survey Form with a pencil. If some child with odd number was not able to produce urine, replace him or her with another sample with even number and mark this in a survey form.
- Transfer approximately 2-3 ml of the urine from selected cups to the capped tubes using a pipette with disposable pipette tip. Use new pipette's tip for every new sampling of urine. Be sure that tubes are tightly covered with the cap. Any concentration effect due to specimen evaporation will cause falsely elevated urinary iodine results, potentially leading to incorrect conclusions of iodine nutrition status.
- Check that number on each tube is corresponding to the number on collection cup and with number on child's wrist. All tubes should be numbered before start of urine collection with permanent marker and standing on the tube rack. There is no need to add any anti-molding or any other additive to the urine. Each tube must have the following labelling: Cluster Number / Sample number.
- Select every fourth salt sample (irrespective of presence or absence of

iodine) for the subsequent testing in the laboratory. Numbers on salt samples should be corresponding to numbers of selected urine samples. For example, you selected 15 urine samples with even numbers (1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29), than select 8 matching salt samples (for example: 1, 5, 9, 13, 17, 21, 25, 29). Label salt bags with: Cluster Number / Sample number.

- At the end of the collection process, tubes with urine should be packed into sealed plastic bags and then - into a cooler. Label the sealed bag with the cluster number and number of specimens contained within. Place sealed bags into a transport container (or cooler). This container with sealed plastic bags should be delivered to the central collection unit.
- While refrigeration of urine samples during the shipping process is preferable, it is not essential. However, each team will receive a cooler box for keeping urine samples during travel in the field. This cooler should be replenished with ice to keep urine samples refrigerated. All urine specimens should be frozen once they are delivered to central collection unit. When all urine sample are collected, they will be airmailed frozen to laboratory in Bangkok in an insulated shipping container on dry ice.
- Salt samples in plastic should be also placed into a bigger zipped transport plastic bag (to keep it dry) and than – to dry transport box. Label the transport plastic bag with the cluster number and number of salt specimen contained within. Deliver them to central collection unit and than to laboratory.
- At the end of collection process, the team leader should review the information on Survey Form to assure that it is complete and appears to be correct. This should be performed while the children are present so that incomplete or incorrect information can be verified or corrected.

ANNEX 4.

Safety precaution recommended by International Council for the Control of Iodine Deficiency Disorders

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Safety measures were applied during the collection of urine and salt. Training and clear guidelines was given to the team and the following instructions was enforced.

1. Use of only disposable cups and pipette tips for urine collection to prevent contamination from specimen to specimen and the possibility of contamination in cleansing the equipment.
2. Discard pipette tips after each transfer of urine from the cup to the tube. Use of surgical gloves to protect survey team members handling urine specimens from the potential of infectious diseases transmitted via urine.
3. Discard used cups, pipette tips and all other disposables into garbage bag.
4. All garbage and disposables was removed into garbage bags and delivered it to provincial hospital for incineration.

Annex 5. **Urinary analysis results - Port Sudan (Red Sea)**

S.No	Red Sea Code	Gender	Iodine (µg/L)	S.No	Red Sea Code	Gender	Iodine (µg/L)
1	1111	Male	519.8	71	1411	Female	319.61
2	1112	Male	756.72	72	1412	Female	761.52
3	1113	Male	266.65	73	1413	Female	625.45
4	1114	Male	776.03	74	1414	Female	907.31
5	1121	Male	1099.89	75	1421	Female	1161.46
6	1122	Male	250.03	76	1422	Female	727.08
7	1123	Male	725.91	77	1423	Female	297.01
8	1124	Male	860.02	78	1424	Female	399.85
9	1131	Male	182.65	79	1431	Female	684.37
10	1133	Male	870.41	80	1432	Female	635.28
11	1134	Male	335.16	81	1433	Female	339.46
12	1141	Male	823.03	82	1434	Female	898.06
13	1142	Male	214.03	83	1441	Female	682.1
14	1143	Male	353.44	84	1442	Female	38.27
15	1144	Male	944.05	85	1443	Female	854.86
16	1151	Male	701.45	86	1444	Female	736.49
17	1152	Male	371.73	87	1451	Female	867.8
18	1153	Male	1313.4	88	1452	Female	476.22
19	1154	Male	747.16	89	1453	Female	884.82
20	1161	Male	749.3	90	1454	Female	761.52
21	1162	Male	250.02	91	1461	Female	938.56
22	1163	Male	300.62	92	1462	Female	382.66
23	1164	Male	600.66	93	1463	Female	728.25
24	1211	Male	269.54	94	1464	Female	649.6
25	1212	Male	1197.46	95	1511	Female	208.28
26	1213	Male	344.35	96	1512	Female	394.56
27	1214	Male	658.49	97	1513	Female	260.52
28	1221	Male	768.75	98	1514	Female	414.31
29	1222	Male	720.06	99	1521	Female	230.17
30	1223	Male	743.6	100	1522	Female	185.72
31	1224	Male	1470.25	101	1523	Female	305.93
32	1231	Male	946.8	102	1524	Female	1049.89
33	1232	Male	1370.58	103	1531	Female	534.79
34	1233	Male	875.63	104	1532	Female	266.65
35	1234	Male	1040.99	105	1533	Female	198.96
36	1241	Male	978.89	106	1534	Female	208.25

37	1242	Male	574.21	107	1541	Female	519.8
38	1243	Male	222.38	108	1542	Female	312.66
39	1244	Male	798.09	109	1544	Female	446.34
40	1251	Male	373.04	110	1551	Female	201.76
41	1252	Male	899.39	111	1553	Female	515.08
42	1253	Male	906.06	112	1554	Female	306.76
43	1254	Male	399.22	113	1561	Female	346.34
44	1261	Male	892.75	114	1562	Female	1265.48
45	1262	Male	824.29	115	1563	Female	256.85
46	1263	Male	562.74	116	1564	Female	341.89
47	1264	Male	675.32	117	1611	Female	431.17
48	1311	Male	985.97	118	1612	Female	213.33
49	1312	Male	871.71	119	1613	Female	718.9
50	1313	Male	665.2	120	1614	Female	351.54
51	1314	Male	512.77	121	1621	Female	190.53
52	1321	Male	140.98	122	1622	Female	960.66
53	1322	Male	157.87	123	1623	Female	168.36
54	1323	Male	381.67	124	1624	Female	343.86
55	1324	Male	551.36	125	1631	Female	659.18
56	1331	Male	307.18	126	1632	Female	83.11
57	1332	Male	370.05	127	1633	Female	1263.74
58	1333	Male	367.84	128	1634	Female	243.72
59	1334	Male	991.67	129	1641	Female	270.83
60	1341	Male	257.24	130	1642	Female	361.32
61	1342	Male	679.84	131	1643	Female	203.18
62	1343	Male	636.38	132	1644	Female	380.04
63	1344	Male	1058.84	133	1651	Female	257.88
64	1351	Male	292.29	134	1652	Female	1267.22
65	1352	Male	508.39	135	1653	Female	1126.38
66	1353	Male	191.36	136	1654	Female	827.82
67	1354	Male	981.72	137	1661	Female	388.16
68	1361	Male	836.94	138	1662	Female	1251.6
69	1363	Male	94.82	139	1663	Female	253.85
70	1364	Male	555.15	140	1664	Female	697.05

Annex 6. Urinary analysis results – Jabal Awliya (Nile Valley)

S.No	Red Sea Code	Gender	Iodine (µg/L)	S.No	Red Sea Code	Gender	Iodine (µg/L)
1	2111	Male	159.76	71	2412	Female	35.63
2	2112	Male	269.43	72	2413	Female	110.56
3	2113	Male	136.38	73	2414	Female	251.55
4	2121	Male	165.43	74	2421	Female	41.19
5	2122	Male	80.75	75	2422	Female	36.88
6	2123	Male	110.8	76	2423	Female	37.53
7	2124	Male	162.14	77	2424	Female	57.34
8	2131	Male	140.72	78	2431	Female	96.63
9	2132	Male	57.11	79	2432	Female	199.37
10	2133	Male	113.45	80	2433	Female	98.13
11	2134	Male	225.2	81	2434	Female	64.4
12	2141	Male	273.2	82	2441	Female	115.6
13	2141	Male	112.74	83	2442	Female	94.16
14	2142	Male	176.72	84	2443	Female	130.77
15	2143	Male	144.93	85	2444	Female	76.23
16	2144	Male	145.74	86	2451	Female	237.67
17	2151	Male	140.12	87	2452	Female	63.1
18	2152	Male	288.13	88	2453	Female	83.25
19	2153	Male	184.71	89	2454	Female	101.83
20	2154	Male	163.02	90	2461	Female	46.65
21	2161	Male	156.13	91	2462	Female	158.26
22	2162	Male	152.97	92	2463	Female	94.65
23	2163	Male	125.05	93	2464	Female	54.59
24	2164	Male	273.54	94	2511	Female	142.33
25	2211	Male	167.31	95	2512	Female	247.97
26	2212	Male	109.65	96	2513	Female	175.77
27	2213	Male	156.98	97	2514	Female	207.23
28	2214	Male	268.83	98	2521	Female	106.94
29	2221	Male	48.57	99	2522	Female	256.5
30	2223	Male	106.58	100	2523	Female	175.3
31	2224	Male	125.83	101	2524	Female	389.89
32	2231	Male	97.59	102	2531	Female	51.69
33	2232	Male	75.6	103	2532	Female	48
34	2233	Male	171.74	104	2534	Female	159.33
35	2234	Male	96.03	105	2541	Female	103.72

36	2242	Male	207.96	106	2542	Female	206.87
37	2243	Male	497.83	107	2543	Female	103.01
38	2244	Male	269.19	108	2544	Female	309.29
39	2251	Male	218	109	2551	Female	265.69
40	2252	Male	64.33	110	2552	Female	126.42
41	2253	Male	126.61	111	2553	Female	235.59
42	2254	Male	261.91	112	2554	Female	155.37
43	2261	Male	110.01	113	2561	Female	87.68
44	2262	Male	139.02	114	2562	Female	129.06
45	2263	Male	131.53	115	2563	Female	258.52
46	2264	Male	173.87	116	2564	Female	131.73
47	2311	Male	260.11	117	2611	Female	173.73
48	2312	Male	76.87	118	2612	Female	31.76
49	2313	Male	486.98	119	2613	Female	131.15
50	2314	Male	193.64	120	2614	Female	248.31
51	2321	Male	144.21	121	2621	Female	213.07
52	2322	Male	145.89	122	2622	Female	231.5
53	2323	Male	665.2	123	2623	Female	384.23
54	2324	Male	232.37	124	2624	Female	246.05
55	2331	Male	243.5	125	2631	Female	184.23
56	2332	Male	243.39	126	2632	Female	224.91
57	2333	Male	314.75	127	2633	Female	159.55
58	2334	Male	249.27	128	2634	Female	204.36
59	2341	Male	213.76	129	2641	Female	327.08
60	2342	Male	158.9	130	2642	Female	166.31
61	2343	Male	166.16	131	2643	Female	184.71
62	2344	Male	284.44	132	2644	Female	161.49
63	2351	Male	305.99	133	2651	Female	72.96
64	2352	Male	298.63	134	2652	Female	150.88
65	2353	Male	346	135	2653	Female	210.67
66	2354	Male	212.27	136	2654	Female	226.05
67	2361	Male	211.53	137	2661	Female	199.74
68	2362	Male	167.78	138	2662	Female	154.65
69	2363	Male	230.34	139	2663	Female	148.4
70	2364	Male	278.15	140	2664	Female	109.92