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THE GOITRE PREVALENCE AND URINARY IODINE STATUS OF PRIMARY SCHOOL CHILDREN IN LESOTHO

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LIST OF SYMBOLS AND ABBREVIATIONS

%	= Percent
dl	= Deciliter
DIT	= Di-iodotyrosine
FNCO	= Food and Nutrition Coordinating Office (in Lesotho)
ICCIDD	= International Council for Control of Iodine Deficiency Disorders
IDD	= Iodine Deficiency Disorders
IEC	= Information, Education and Communication
IIH	= iodine induce hyperthyroidism
IQ	= Intelligence Quotient
KI	= Potassium iodide
KIO3	= Potassium iodate
l	= litre
mg	= milligrams
MIT	=Mono-iodotyrosine
n	= sample size
NaI	= Sodium Iodide
NCHS	= National center for Health Statistics (Ohio)
NGOs	= Non Governmental Organizations
NIDDCP	= National Iodine Deficiency Disorder Control Program
NUL	= National University of Lesotho
PEM	= Protein Energy Malnutrition
ppm	= Parts per million
RDA	= Recommended Daily Allowance
SSRFU	= School Self Reliance Food Unit (in Lesotho)
SCN	=Thiocyanate
TLQA	= Total Laboratory Quality Assurance (TLQA)
T3	= Tri-iodothyronine

T4	= Thyroxine
Tg	=Thyroglobulin
TSH	= Thyroid Stimulating Hormone
TGR	= Total Goitre Rate
μg	= Micrograms
UNICEF	= United Nations Children's Fund
USA	= United States of America
VGR	= Visible Goitre Rate
VTO	= 5-Venyl-2 thio-oxazoliodone
WHA	= World Health Assembly
WHO	= World Health Organization

GLOSSARY

Colloid: Constituent of the thyroid gland in which thyroid hormone storage takes place.

Cretinism: A condition associated with severe iodine deficiency and goitre commonly characterized by mental deficiency, deaf mutism, squint, disorders of stance and gait, stunted growth and hyperthyroidism.

Creatinine: A product of metabolism in muscle, which is excreted in the urine at about the same level from day to day.

Deaf-mutism: State of being both deaf and dumb.

Endemic: Occurrence of a disease confined to a community or defined population in which the prevalence of the condition exceeds a critical level, for example, 5 percent prevalence in endemic goitre.

Foetus: The unborn offspring, the child in the womb after the third month of pregnancy.

Gait: Manner of walking.

Goitre: Enlarged thyroid gland.

Goitrogens: Chemical substances in the diet which cause goitre due to action on the thyroid gland in blocking thyroid hormone synthesis or increasing kidney excretion of iodide. Their effect can usually be overcome by increasing iodine intake.

Hormone: Specialized chemical secretions of endocrine glands, which are released directly into the blood, and exert specific effects on their target organs.

Hyperplasia: Increased number of cells due to stimulation.

Hyperthyroidism: A condition due to elevated levels of thyroid hormones, which produce a rapid heart rate and other features of a nervous state (trembling, excessive sweating, irritability and weight loss).

Hypothyroidism: The result of a lowered level of circulating thyroid hormone slowing of mental and physical functions.

Iodine deficiency disorders (IDD): The effects of iodine deficiency, which show up during every stage of life.

Iodisation (of salt): The general term covering fortification of common salt with potassium iodate or potassium iodide.

Iodised oil: An organic compound of iodised ethyl esters of fatty acids of various kinds of oil. Soya bean and walnut oil have also been used to make iodised oil (Lipiodol & Oriodol). Only oils containing unsaturated fatty acids can be iodised, available by injections and by mouth.

Iodophors: Iodine containing antiseptics used in the dairy industry.

Lipiodol: Brand name of iodised poppy seed oil capsules used for the oral treatment of severe iodine deficiency

Myxedematous: An oedema (swelling), which occurs due to poor thyroid functioning.

Neonatal hypothyroidism: Condition in the newborn with thyroid hormones deficiency.

Nutrient: Substance that supplies the body with the elements necessary for normal functioning.

Perinatal (mortality rate): Number of foetal deaths after the 28th week of pregnancy, plus the number of deaths of infants under seven days of age, per 1000 live births.

Phalanx: Digital bone of a finger.

Prevalence (rate): Number of persons with the same disease at the same time per population at risk.

Prophylaxis: An intervention aimed at preventing the occurrence of a disease.

Squint: Inability of the eyes to look in the same direction together.

Stance: Position of body when standing.

Still birth: Birth of a dead foetus.

Stunting: Shortness due to retarded growth.

Thyocyanate: Chemicals known to have goitrogenic potential.

Thyroid: An endocrine gland, which secretes a hormone thyroxine. It is located at the base of the neck and extends on both sides of the midline

Thyroxine: A hormone, which contains iodine and is synthesized and secreted by thyroid gland. It plays a vital role in the normal growth and development of the human brain in early life and metabolic processes.

Triodothyronine: One of the thyroid hormones, which utilizes 3 iodine molecules.

Thyroid stimulating hormone: Hormone, which comes from the pituitary gland at the base of the brain and controls thyroid activity.

Iodine: A non-metallic element belonging to the halogen group. It is a black crystalline substance having a density of about five. It melts at 114 degrees Centigrade and boils at a slightly higher temperature, giving off a characteristic violet vapour. Its atomic number is 53 and atomic weight is 126.92.

CHAPTER 1

INTRODUCTION

1. BACKGROUND TO THE STUDY

Iodine is an essential nutrient for the synthesis of thyroid hormones, which help regulate a wide range of physiological processes including metabolic rate, calorigenesis, thermoregulation, growth and development of most organs and protein synthesis (Hurrel, 1997). The normal human requirement is 150μg per day and about 90 percent of this normally comes from food and the rest from water. Food crops and water derive iodine from the soil and studies have shown that some soils contain more iodine than others (Hetzel & Pandav, 1994, p.16). Soils, which are poor in iodine content, are common in mountainous regions, in the plains and river basins where iodine is periodically washed away by glaciers, heavy rainfall and floods. Crops grown on these soils are deficient in iodine and as a result iodine deficiency occurs in human and animal population dependent on them.

1.1 CONSEQUENCES OF IODINE DEFICIENCY

The deficiency of iodine has several important health consequences that together are called "Iodine Deficiency Disorders (IDD)" (Hetzel, 1993b, p.23). According to the World Health Organisation (WHO, 1995), the effects of iodine deficiency begin before birth and have various results throughout the life cycle. These results include stillbirths, abortions, congenital abnormalities, goitre, cretinism and impaired mental function associated with hypothyroidism.

WHO (1994) describes goitre as an enlargement of the thyroid gland. It is an obvious disorder, which can lead to significant morbidity due to compression and altered thyroid function. WHO (1994) describes, furthermore, that cretinism

is an extreme form of iodine deficiency disorders. Cretins often suffer from growth retardation or dwarfism. They are severely mentally retarded and the majority of them are deaf mute. The most devastating of iodine deficiency consequences are on the developing human brain. Iodine deficiency may result in irreversible brain damage in the foetus and infant; and in retarded psychomotor development in the child. The effect of iodine deficiency on mental development may lead to reduction in learning capacity. Studies have shown that severely iodine deficient children have intelligence quotients (IQs) that are 10 to 15 points lower than those of children who do not suffer from iodine deficiency disorders. The cumulative consequences in iodine deficient populations spell diminished performance for the entire economy of affected nations.

1.2 GLOBAL PREVALENCE OF IDD AND THE RECENT PROGRESS IN ITS ELIMINATION.

Iodine deficiency is both easy and inexpensive to prevent, but nevertheless continues to be a significant public health problem in many countries (WHO, 1993) (Appendix 1). This is probably due to their geographical location, socio-economic, cultural and political limitation to adequate intake of iodine. It is estimated that more than one billion people concentrated primarily in less developed countries are unable to consume adequate levels of iodine (Marberly, 1994). WHO (1994) estimates that 1571 million people world wide live in iodine deficient environments and thus at risk of IDD.

IDD are a significant public health problem in 118 countries (WHO/UNICEF/ICCIDD, 1993; WHO, 1994). It is recently estimated that 43 million people worldwide are suffering from varying degrees of brain damage (UNICEF, 1998). There are an estimated 11 million overt cretins and some 760 million people have goitres. These estimates of obviously affected people have placed iodine deficiency among the most extensive nutritional problems in the world (Van Der Haar, 1997).

Since 1986, the International Council for Control of Iodine Deficiency Disorders (ICCIDD) has been instrumental in focusing the world's attention on iodine deficiency disorders (Pandav & Rao, 1997, p.47). The goal of virtual elimination of IDD as a public health problem by the year 2000 was accepted by the United Nations system in 1990 when two major decisions were taken (Hetzel, 1994, p.12). The first major decision was the Resolution of the 43rd World Health Assembly (WHA) in Geneva calling for the elimination of IDD as a public health problem by the year 2000. The second major decision was made by the World Summit for Children, which approved a Plan of Action for the future health and education of children throughout the world. This Plan of Action was signed by 71 Heads of State who attended the World Summit and were followed by 88 high level government representatives who also signed the Plan of Action making a total of 159 countries committed to the Plan (Hetzel, 1994, p.23). The World Declaration and Plan of Action, which was adopted by the International Conference on Nutrition 1992 reaffirmed this IDD goal and provided strategic guidance, including emphasis on salt iodisation (IDD Newsletter, 1996).

Iodisation of all edible salt is a long-term sustainable preventative solution to eliminate IDD. Much progress has been achieved since the creation of ICCIDD in 1986 (Hetzel, 1994, p.7). For example, the United Nations' Children Fund (UNICEF, 1998) states that of the countries that had IDD problems in 1990, 26 countries now iodise over 90 percent and 14 countries iodise between 75 percent and 80 percent of their edible salt. It is further estimated that up until 1990, about 40 million children were born each year at some risk of mental impairment due to iodine deficiency in their mothers' diets. By 1997 that figure was probably closer to 28 million, which is still too high but represent a clear and rapid decrease.

1.3 IDD SITUATION IN LESOTHO AND THE PROGRESS IN ITS ELIMINATION

Lesotho is a country with an area of 30,335sq km and completely land-locked by the Republic of South Africa (Wolde-Gebriel, 1993). About 75 percent of the country is mountainous and it is estimated that only 300 000 ha, or 10 percent of the land is arable. Ecologically the country is divided into four distinct ecological zones mainly on the basis of altitude, namely, Mountains (Highlands), Foothills, Senqu river valley and Lowlands. The country is divided into ten administrative districts (Appendix 2) all of them having some parts of the various ecological zones. All the areas in the country have an altitude of more than 1500 metres above sea level. Climate varies with differing topography whereby the Mountains have cool summers and cold winters often accompanied by snow, while the lowlands have warmer summers with occasional rain and very dry but cold winters. This geographical situation makes it possible that iodine has been leached from the soil in Lesotho.

The prevalence of IDD in Lesotho was, first recorded by Munoz and Anderson (1960), when they conducted a national survey on the Nutritional and Health status of children in Lesotho. They reported a total goitre rate (TGR) of 41 percent and a visible goitre rate (VGR) of 14 percent in school children (6-13 years) indicating severe IDD. The national nutrition survey conducted in 1988 revealed a goitre prevalence of 42 percent in women of childbearing age and 21 percent in school children between the age of 6 and 13 years indicating severe and moderate IDD respectively (Nyapisi, 1988). The urinary iodine assessment in the Mountains and Lowlands showed median values of 35µg/l and 55µg/l respectively indicating moderate to mild IDD.

The National Micronutrient survey was conducted in 1993 as the second phase of the 1992 nation-wide nutrition survey, which had more emphasis on Protein Energy Malnutrition (PEM) but not on the micronutrients (Wolde-Gebriel, 1993). This survey revealed a TGR of 42.5 percent and VGR of 15.3 percent among primary school children aged between 6 and 16 years indicating severe IDD. A

recent baseline cross-sectional study conducted at Mohale Dam catchment area indicated goitre prevalence of 17.5 percent and the median urinary iodine concentration of 13µg/l in children aged 10 to 14 years indicating mild to severe IDD in this area (Jooste *et al.*, 1997). The above studies show that Lesotho is one of the countries where iodine deficiency is a public health problem.

Following the 1993 National Micronutrient survey, the legislation on universal salt iodisation was drafted in 1994 as a long-term intervention. The regulations were added to the Legal notice No.13 of 1999, section 71 of the Public Health Order 1970 in March 1999 in the government Gazette (Appendix 3). The Legislation states that food grade salt or other salt intended for both human and animal consumption, which is exported to Lesotho must contain not less than 40ppm and not more than 60ppm of iodine on entering the country. The exemptions on these regulations include salt intended for use in the manufacture of compound food stuffs which is packed in bags of 20kg or more and labeled "non iodised salt" and salt used for experimental purposes. It allows customs officials to do random check tests of the salt at entry points and health inspectors at retail level.

The legislation was promulgated in March 2000. After the promulgation, the Lesotho micronutrient task force, which is coordinated by the Food and Nutrition Coordinating Office (F.N.C.O) initiated workshops for traders and customs officials. The purpose of the workshops was to ensure awareness and enforcement of the regulations, which included provision of the salt test kits. The copies of the legislation were also sent to the salt plants near Lesotho and a plan is to visit all the salt plants in South Africa before 2001 to ensure that all salt meant for animal and human consumption which is exported to Lesotho is iodised.

Lesotho gets most of its salt from South Africa and the current legislation in South Africa (Appendix 4) states that salt produced or imported shall contain between 40 and 60ppm on entering the country and the salt exported from the country may contain more than 60ppm of iodine. The exemptions on these

regulations include salt indented for use in the manufacture of compound foodstuffs, which is packed in bags of 20kg or more, also meant for animal consumption and salt available at pharmacies in packages of 1kg or less and labeled "non iodised salt".

A study conducted by the Department of Health (1997) in South Africa indicated that no iodine was detected in 12.3 percent of the salt samples. A recent study on salt iodine level in Lesotho showed that 15.3 percent of households in Lesotho use non iodised salt of which 14.3 percent was salt packed in 20kg bags or more (Sebotsa, 1998). It was also indicated in this study that 20 percent of the household salt was iodised at less than 20ppm, which was the cut-off level for defining adequately iodised salt at household level during the time of study (recently 15ppm is used as the cut-off level for defining adequately iodised salt at household level). These studies indicate that salt iodisation in South Africa affects the availability of iodised salt in Lesotho. There is a possibility therefore that after the Legislation in Lesotho has been enforced all salt meant for both animal and human consumption, which is exported to Lesotho will be iodised.

The administration of iodised oil to the entire population has been proposed as an emergency prophylactic and therapeutic approach in areas with severe iodine deficiency where universal salt iodisation has not yet been successfully introduced (Gutekunst *et al.*, 1992; Delange, 1996). Following the 1993 Micronutrient survey, iodised oil capsules were distributed as a short-term intervention. The first supplementation with iodised oil capsules, each containing 200mg of iodine, started in February 1995 and continued to May 1996. The second supplementation was done in January 1997 to February 1998. Supplementation was done to all the people aged between 2 and 49 years at schools and clinics and the target population was the primary school children. Possibly each capsule was adequate for a year's coverage and each person was supposed to receive supplementation both in 1995 to 1996 and in 1997 to 1998. This information was recorded in each person's health booklet (Bukana) and duplicated in the clinics and schools record books depending on

where supplementation took place. It is, however, possible that some people did not receive supplementation, as this was not compulsory.

According to Dunn and Van Der Haar (1990, p.32), the two most valuable means for assessing the severity of iodine deficiency in a given area are the prevalence of goitre and the urinary excretion of iodine. Goitre is usually the most obvious sign of iodine deficiency, but brain damage, mental retardation, miscarriages and child mortality are the more serious consequences of IDD. It is therefore important to document the goitre prevalence in a population to determine whether these more serious consequences are likely to be present. Almost all iodine in the body is eventually excreted in the urine, thus measurement of iodine in the urine provides a good index of the iodine taken in. Hetzel (1993a, p.26) states that because goitre enlargement can be caused by several factors, confirmation that the cause is iodine deficiency must be done by urinary iodine analysis.

2. MOTIVATION FOR THE STUDY

Studies conducted since 1960 have shown that mild to severe IDD exist in Lesotho (Munoz & Anderson, 1960; Nyapisi, 1988; Wolde-Gebriel, 1993). The short and long term interventions are aimed at controlling or preventing IDD in countries. Both iodised oil supplementation and introduction of the universal salt iodisation were used in an attempt to control and prevent IDD in Lesotho. However, due to inadequate intake of iodine and other factors affecting iodine prophylaxis with iodised oil and iodised salt, iodine deficiency might currently still be a public health problem in Lesotho. Figure 1 summarises the IDD situation, control and prevention in Lesotho and the questions that motivated the present study.

The present study was therefore undertaken in an attempt to determine the current IDD situation in Lesotho five years after the 1993 National Micronutrient survey and after IDD interventions (the drafting of the universal salt iodisation legislation and the distribution of iodised oil capsules).

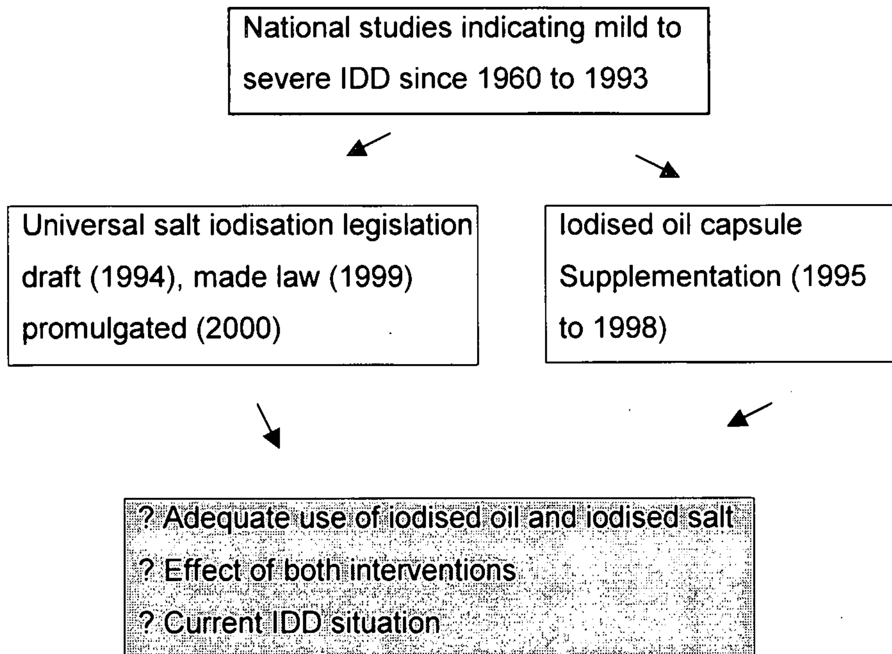

Figure 1. Summary of the motivation for the study

3. SIGNIFICANCE OF THE STUDY

From the results of the present study it could be possible to highlight the need for further studies and long term monitoring of the situation after the legislation has been enforced. Furthermore, the findings of the study could supply important information on whether the normal thyroid function is attained and maintained in the target population (school children) and whether or not it is necessary to continue with the distribution of iodised oil capsules in some or all of the districts. The findings could also contribute important information to the current knowledge of where Lesotho stands as far as urinary iodine and goitre status is concerned. It could also be used as a monitoring progress towards elimination of IDD as a significant public health problem.

4. AIMS AND OBJECTIVES OF THE STUDY

4.1 AIM

To assess the current urinary iodine and goitre status of the primary school children in Lesotho as well as the previous use of iodised oil capsules and the current use of iodised salt.

4.2 OBJECTIVES

1 To assess the urinary iodine concentration and thyroid size of primary school children in Lesotho.
2 To estimate the urinary iodine deficiency and the prevalence of goitre in each district, each ecological zone and at a national level.
3 To compare the prevalence of goitre in females and males at primary schools in Lesotho.
4 To determine whether at least 95 percent of primary school children received iodised oil capsules both in 1995 to 1996 and in 1997 to 1998 in an attempt to estimate the coverage on iodised oil supplementation.
5 To determine the iodisation level of salt used by households presented by school children in Lesotho, in an attempt to estimate the coverage in the use of iodised salt.

5. STRUCTURE OF THE DISSERTATION

Chapter 1 gives the introduction of the dissertation. In the literature review (Chapter 2), iodine deficiency disorders, their detection and strategies in their elimination are discussed according to the relevant literature. In Chapter 3 the methodology used in this study is given. Results of this study are given in Chapter 4. Chapter 5 presents the discussion of the results followed by conclusions and recommendations in Chapter 6. The cited literature is given in the references. Examples of questionnaire, Legislations, and palpation procedure and urinary iodine analysis method used in this study are given as appendices and the summary is given at the back of the dissertation.

6. LIMITATIONS OF THE STUDY

Titration, which is a more precise quantitative measure of the content of iodine in salt, was not used in this study due to limited funds. The rapid (spot) test method, which gives a qualitative indication of whether or not iodine is present in the salt, was therefore used for salt iodine analysis.

10 urine samples were obtained from each school regardless of the school size. With this sample size, it was difficult to adjust the median urinary iodine concentrations proportional to the size of the country, districts and ecological zones during statistical analysis. All the results except the median urinary iodine concentration were therefore proportionally adjusted.

CHAPTER 2

LITERATURE REVIEW

1. INTRODUCTION

Iodine is a trace element present in the human body in minute amounts (15-20mg) (Hetzel, 1987, p.549; Delange, 1994). It is sparsely distributed over the surface of the earth and it is an essential substrate for the synthesis of thyroid hormones. The daily requirement of iodine is at least equal to the amount of hormonal iodine degraded and un-recovered daily by the thyroid gland (Delange, 1994). When the physiological requirements of iodine are not met in a given population, a series of functional and developmental abnormalities occur (Tyabi, 1985, p.12; WHO, 1995).

Because of grave consequences of IDD, detection and elimination are important. Detection of iodine deficiency can be done using both the biochemical and clinical indicators. Once the presence of iodine deficiency is established a program to deal with it must be developed and this will deal with prevention and elimination of IDD.

An IDD intervention that is appropriate for the specific conditions in a given country should be initiated when needed. The effectiveness of these programs should be measured. Information, Education and Communication (IEC) are the most important components of IDD control program. Once the IDD control program is in operation, periodic monitoring and evaluation of its process indicators (e.g. iodine content of salt and the coverage of adequately iodised salt) and outcome indicators (e.g. urinary iodine concentration, goitre rate, thyroid stimulating hormone, thyroid hormones) is mandatory.

2. THEORETICAL MODEL FOR THE STUDY

Figure 2 presents a research model adapted for the study (Dunn & Van Der Haar, 1990; p24; WHO, 1993; Stanbury & Pinchera, 1994, p.75; WHO/UNICEF/ICCIDD, 1994). According to this model, factors relevant to IDD, IDD detection, control, monitoring and evaluation will be discussed.

3. FACTORS RELATED TO IODINE DEFICIENCY

There are several factors related to iodine deficiency and they are discussed in this section. These factors include contributing, predisposing and indispensable factors.

3.1 CONTRIBUTING FACTORS

3.1.1 Iodine bioavailability

The major factor controlling the amount of bio-available iodine in the diet is iodine content of food, which depends on the iodine level in the soil and access to sea foods and fortified foods such as salt (Aurthur *et al.*, 1993). The iodine content of food actually consumed is not necessarily equivalent to that of raw food since some iodine is lost during cooking. For example, losses of about 20 percent occur in the iodine content of fish by frying or grilling and as much as 50 percent by boiling (WHO, 1994). Iodine contained in food is generally well absorbed with the possible exception of people suffering from PEM, which is of particular concern in high prevalence, endemic goitre areas of developing countries (Hetzel, 1993b, p.6).

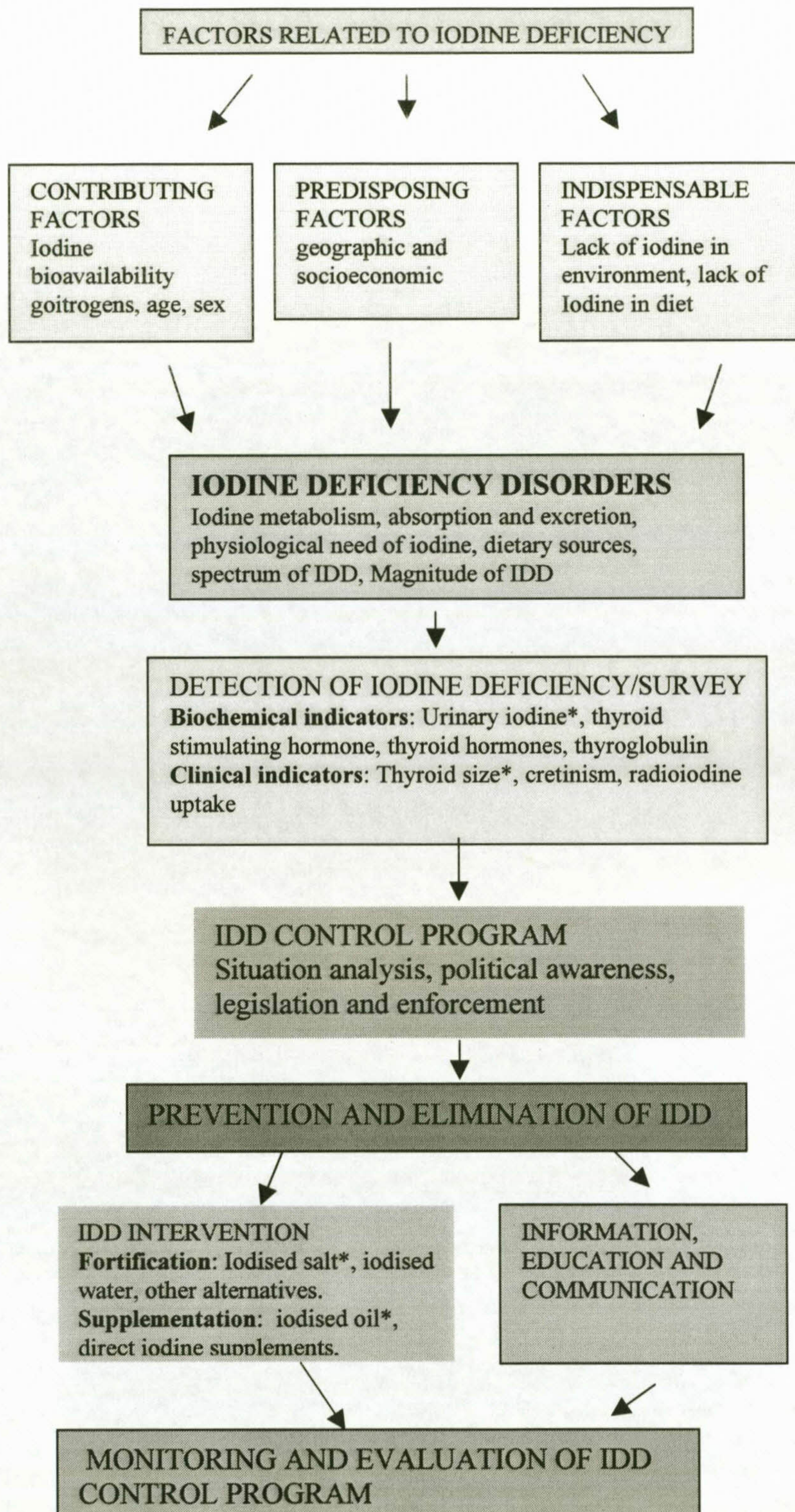

Figure 2. The theoretical model adapted for the study

* Variables measured in this study

The deficiency of some nutrients can decrease iodine bioavailability. Selenium deficiency for instance, prevents the conversion of T4 to T3 in the liver (Aurthur *et al.*, 1993) and it also increases thyroid size in iodine deficient animals (Beckett *et al.*, 1993). Vitamin A affects thyroid hormones at several levels. Thyroperoxidase is a haem enzyme requiring iron (Beard *et al.*, 1990). Therefore in iron deficiency, thyroid metabolism is impaired with an inability to control body temperature.

3.1.2 Goitrogens

Food components do not appear to greatly influence iodine absorption but can reduce its utilization for the production of hormones (Hetzel, 1993a, p.544). Such components are termed goitrogens and are considered to be important only when iodine intake is low. Goitrogenic factors in the diet or environment other than iodine deficiency can play a role in the etiology of IDD (Delange, 1994). The role of these substances had to be considered as endemic goitre has been found in regions with no iodine deficiency.

Goitrogens are substances occurring naturally in foods and can cause goitre by blocking thyroidal absorption or utilization of iodine (Lutz & Pruzytulski, 1997, p.146). The best known of these substances are sulphur containing thionamides derived from vegetables of the Cruciferae family, particularly the Brassica genus such as cabbage, turnips, brussels sprouts, sweet potatoes, rapeseeds, peanuts and soybeans. Their anti-thyroidal action is related to the presence of thioglucosides which after digestion, release thiocyanate (SCN) and isothiocyanate (Delange, 1994). The SCN ion has a molecular volume and charge similar to that of iodide and competes with iodide for uptake into the thyroid (Thilly *et al.*, 1993). Both SCN and isothiocyanate are however inactivated by cooking. Some studies suggest that local water may contain goitrogenic substances from geologic origin or possibly from *Escherichia Coli* pollution in the water (Delange, 1994).

Another important group of goitrogens is the cyanoglucosides. This has been found in several staples like cassava, maize, bamboo shoots, sweet potatoes and lima beans. After ingestion these glucosides release cyanade, which is detoxified by conversion to SCN (Delange, 1994). In Zaire and some other African regions cassava is a staple food from which during the processing SCN is liberated. The determining factor involved in the goitrogenic action of cassava is the balance between dietary supplies of iodine and SCN (Delange, 1994), therefore the effects of SCN can be eliminated by increasing the supply of iodine (Lamberg, 1993).

The goitrogenic effects of some other thionamides, such as 5-vinyl-2-thio-oxazolione (VTO, goitrin) and flavonoids inhibit the activity of thyroperoxidase in the oxidation of iodine and the formation of tyrosine dimers. These goitrogens depend on a block in the thyroidal synthesis of hormones and are possibly only partially eliminated by more iodine. VTO occurs in the seeds of various Brassica. Goitrin in milk has been linked to endemic goitre and iodine deficiency in Finland (Delange, 1994; Lamberg, 1993). VTO and flavonoids are eliminated by intake of more iodine (Delange, 1994).

3.1.3 Age

Where iodine deficiency is endemic, it may affect the entire population with different age groups manifesting different physiological and pathological consequences (WHO, 1993). The prevalence of goitre increases with age reaching a maximum after the first decade (WHO, 1993; Delange, 1994). For example in Lesotho, the prevalence of goitre was found to increase with age in both sexes in up to the age of 12 to 14 years (Jooste *et al.*, 1997). Several studies confirmed that iodine deficiency in children is characteristically associated with goitre, of which the prevalence increases with age (Hetzel, 1989, p.7).

Iodine deficiency in the foetus due to inadequate iodine status of the mother is associated with a greater incidence of stillbirths, spontaneous abortion, congenital abnormalities and may lead to cretinism (WHO/UNICEF/ICCIDD, 1993). As a significant degree of neurological development occurs within weeks of conception and especially during the first month of foetal growth, it is imperative that women have adequate iodine stores during the first trimester of pregnancy. The increased biological needs for iodine in pregnant women also implies a greater risk of becoming iodine deficient and developing goitre.

3.1.4 Sex

Studies have shown that girls have a higher prevalence of goitre than boys (Delange, 1994). In reviewing the prevalent data on goitre throughout the world, females from adolescence onwards have a higher prevalence of goitre than males, perhaps due to the differences in the metabolism of iodine during adolescent growth (WHO, 1993). For example in the Netherlands, the prevalence of goitre among adolescents in 1985 to1986 varied between 19 and 39 percent among girls and between 7 and 31 percent among boys (Brussard *et al.*, 1997b).

In India the goitre prevalence was 23.6 percent in females and 9.7 percent in males amongst school children aged 7 to 18 years (Mallik *et al.*, 1998). In Lesotho similar observations were indicated in most studies conducted since 1956. For example, the total goitre rate was 41.8 percent in females and 40.0 percent in males in school children aged between 6 and 13 years (Munoz & Anderson, 1960), 46.5 percent in females and 22.5 percent in males in clinic attendants aged 12 years and over (Mpeta, 1987). In 1993 the prevalence of goitre was 34.4 percent in males and 41.6 percent in females in school children aged 6 to 16 years (Wolde-Gebriel, 1993). A recent study conducted at Mohale Dam indicated the prevalence of goitre in school children between 5 and 15

years as 12.4 percent in boys and 20.0 percent in girls (Jooste *et al.*, 1997).

3.2 PREDISPOSING FACTORS

3.2.1 Geographic

Broad geographic areas exist in which the population daily intake of iodine is below the recommended dietary allowance and in which the population is affected by IDD (Hetzel, 1987, p.548). These areas are usually mountainous because the soils lowest in iodine are those that were covered longest by the quaternary glaciers and snow and when these melted, most of the iodine leached out of the ground beneath. Iodine deficiency also occurs in lowlands far from the oceans by regular flooding and heavy winds (Koutras *et al.*, 1980). Because low levels of environmental iodine and associated dietary intakes of iodine exist in specific geo-ecological areas or zones, IDD are generally localized in those zones. Within countries the levels of IDD therefore vary significantly from area to area (WHO, 1993). For example in Lesotho the prevalence of goitre was found to be higher in the Mountainous (highlands) regions than in the Lowlands (Munoz & Anderson, 1960; Mpeta, 1987; Wolde- Gebriel, 1993).

3.2.2 Socio-economic

Although entirely preventable, iodine deficiency disorders still prevail because of various socio-economic, cultural and political limitations to adequate programs of iodine supplementation (Thilly *et al.*, 1980). In Lesotho, the prevalence of goitre was higher in school children with low socio-economic status and those living in the mountainous region (Wolde-Gebriel, 1993). In Indonesia, children who showed high iodine content in their urine lived in better socio-economic status (Pardede *et al.*, 1998). In South Africa, low urinary iodine concentrations (<0.16 μmol/L) were found

in low socio-economic children in three schools compared to children in a higher socio-economic community in the Langkloof area (Jooste *et al.*, 2000).

Some studies demonstrated that endemic goitre preferentially affects rural populations and low-income groups living under poor sanitation conditions (Hetzel, 1993). Other forms of malnutrition notably PEM and vitamin A deficiency may have secondary effects on iodine nutritional status (Beard *et al.*, 1990; Hetzel, 1993b, p.538). Severe PEM affects thyroidal function and metabolism of thyroid function.

3.3 INDISPENSABLE FACTORS

3.3.1 Lack of iodine in the environment

The iodine cycle in nature affects the distribution of this element in soil, plants and animal within the system (Hetzel & Pandav, 1994, p.37). Iodine is volatile, so that every year some 400 000 tonnes of iodine escape from the surface of the sea. The concentration of iodide in the sea is about 50-60μg per litre; in the air it is approximately 0.7μg per cubic metre. The iodine in the atmosphere is returned to the soil by rain, which has concentrations in the range, 1.8 to 8.5μg per litre. In this way the cycle is complete. The return of iodine however is slow and small in amount compared to the original loss, and subsequent repeated flooding ensures that iodine deficiency in the soil continues. There is no natural correction and iodine deficiency persists in the soil indefinitely. All crops grown in these soils will be iodine deficient and as a result human and animal population, totally dependent on food grown on such soil become iodine deficient.

3.3.2 Lack of iodine in the diet

Where the soil is lacking in iodine, locally produced foods will provide inadequate dietary iodine and unless the source of iodine is supplied from outside, people consuming these diets will develop the deficiency (Hetzel, 1993b, p.68; Van Der Haar, 1997; UNICEF, 1998). The iodine content of plants grown in iodine deficient soils may be as low as 10μg/kg compared to 100μg/kg dry weight in plants in a non iodine deficient soil (Hetzel & Pandav, 1994, p.47). In Lesotho, the prevalence of goitre was found to be high since 1956 and the soil and water did not contain iodine in a Micronutrient study conducted in 1993 (Wolde-Gebriel, 1993).

An insufficient dietary supply of iodine is the main cause of endemic goitre and cretinism (Hetzel, 1993a, p.539). For example endemic goitre has been scientifically documented for decades and is still present in Germany due to consumption of foods low in iodine content (Delange *et al.*, 1997). In the Netherlands it was found that iodine intake levels were below the recommended amount in women and this group had a higher prevalence of goitre (Brussard *et al.*, 1997a). Several studies also indicate that vegans not consuming iodine supplements, seaweed and other related products rich in iodine, have inadequate intakes of dietary iodine. For example, urinary iodine was significantly lower with the lacto vegetarian diet than with the normal protein rich diets in a recent study conducted in Germany (Remer *et al.*, 1999).

The indirect evidence of greater deficiency problems with vegetarian diets compared with meat containing mixed diets might be seen in the fact that iodine deficiency is usually most prevalent in rural population which primarily consume plant foods (Sullivan *et al.*, 1997). However, a low iodine concentration in the soil affects the iodine content of both plant and animal products and in industrialized countries iodine replacement in animal feed is more common than in soil (Remer *et al.*, 1999). Endemic goitre was widespread in Britain but has declined, most notably since the

1960s (Phillips, 1997). Its reduction was probably due to changes in farming practice, especially iodine supplementation in dairy herds, which has resulted in iodine contamination of milk and dairy produce. Cao *et al.* (1994) and Delong *et al.* (1997) state that as long as alternative methods of iodine supplementation based on iodine replacement in the soil are used sporadically, the iodine content of fruits and vegetables will remain extremely low in most regions worldwide.

4. IODINE DEFICIENCY DISORDERS

This section discusses the spectrum of IDD together with iodine metabolism, absorption, excretion, as well as the physiological needs and the sources of iodine.

4.1 IODINE METABOLISM, ABSORPTION, EXCRETION AND FUNCTION

Iodine is ingested with food, absorbed as iodide from the gut and taken up as iodide through an active mechanism by the thyroid gland (Lee *et al.*, 1999). The iodide is released by the thyroid cells into the colloid follicle phase between the cells, where it is oxidised by hydrogen peroxide from the thyroid peroxidase system. It then combines with tyrosine in the thyroglobulin to form mono-iodotyrosine (MIT) and di-iodotyrosine (DIT). The oxidation process then continues with the coupling of MIT and DIT to form the Iodotyrosines. Finally the iodised thyroglobulin including the iodised amino acids is absorbed back into the thyroid cells by a process called "pinocytosis" (Lee *et al.*, 1999). It is then exposed to proteolytic enzymes, which break it down to release the thyroid hormones; thyroxine (T4) and tri-odothyronine (T3) into the blood (Hetzel, 1989; Brody, 1994). The main product secreted into the blood from the thyroid gland is T4 and most of the T3 is formed in other tissues by mono-de-iodination of T4 (Lamberg, 1993; Hurrel, 1997).

The regulation of thyroid hormones is a complex process, which involves the thyroid, the pituitary, the brain and the peripheral tissues (Dunn & Van Der Haar, 1990; Hetzel, 1994, p.37). Thyroid secretion is under the control of the pituitary gland through the Thyroid Stimulating Hormone (TSH). TSH therefore activates all stages of iodine metabolism from the trapping of iodine to the secretion of T4 and T3. TSH secretion is also under the control of the brain through the thyrotophin releasing hormone (TRH), which is released from the hypothalamus, a small region at the base of the brain, which is very important for the control of all the pituitary hormones.

The thyroid has to trap about 60μg of iodine per day to maintain adequate supply of the thyroid hormones (Hetzel, 1994, p.21). This is possible because of the very active trapping mechanism, which maintains a gradient of 100:1 between the thyroid cells and the extra-cellular fluid. In iodine deficiency this gradient may exceed 400:1 in order to maintain the output of thyroxine.

Iodine is believed to be absorbed efficiently (about 90%) (Hurrel, 1997) and is absorbed from all portions of the intestinal tract. The thyroid cells use 33 percent of the absorbed iodine for the synthesis of T4 and T3 and the remaining 67 percent is predominantly excreted in the urine. T4 and T3 are, degraded by the liver after performing their functions and the iodine content is excreted in bile (Lutz & Pruzytulski, 1997, p.136). Iodine leaves the body mainly as iodide with the urine (85-90%) and partly with the faeces as organically bound iodine (Lamberg, 1993). The level of urinary excretion correlates well with the level of intake so that it can be used to assess the level of iodine intake (WHO, 1994).

Iodine can be found in muscle, thyroid gland, skin and skeleton (Hetzel, 1993b, p.53). The greatest concentration is in the thyroid gland in the neck. The body of the healthy human contains 15 to 20mg of iodine (Lutz & Pruzytulski, 1997, p.137) of which 70 to 80 percent is in the thyroid

gland which weighs only 15-20g (Hetzel, 1993b, p.34; Hetzel & Pandav, 1994, p.23).

Thyroid function is essential for normal growth and development (Hetzel, 2000, p.624). Thyroid hormone deficiency from an absent thyroid, congenital thyroid defect or severe iodine deficiency, leads to severe retardation of growth and maturation of almost all organ systems. Body weight does not increase and there is retardation of bone growth. Estimates of cellular growth show that retardation is most apparent in tissues that are rapidly proliferating thus the sensitivity of different organs to iodine and thyroid deficiency varies (Hetzel & Pandav, 1994, p.8; Hetzel, 2000, p.624). The brain is particularly susceptible to damage during foetal and early postnatal period (Hetzel, 2000, p.624). This is because at birth, the child's brain is very immature and less than a third of its mature weight. The major effect of foetal iodine deficiency is endemic cretinism (Hetzel & Clugston, 1999, p.257).

4.2 THE PHYSIOLOGICAL NEED FOR IODINE

As in the case of other trace elements the estimation of the physiological or "normal" requirement of iodine is not easy and depends on many factors (Lamberg, 1993). In 1952 an expert group of World Health Organizations decided that the intake of 100 to 150μg should be regarded as normal (WHO, 1994). This amount should be adequate for correcting iodine deficiency, for compensating for possible temporarily increased demands of iodine and for preventing the effects of environmental goitrogens.

Anderson (2000, p.140) indicates that an intake of 150μg/day of iodine has been suggested as sufficient for all adults and adolescents. The Recommended Daily Allowances (RDA) for pregnant and lactating women is increased by 25μg and 50μg respectively (Anderson, 2000, p.140) resulting in 175μg and 200μg respectively (Hetzel, 2000, p.622). The

RDA is 40μg for infants up to six months of age and 50 μg for older infants. The RDA for children is between 70 and 120μg increasing with age (or body size). Based on studies of balance and excretion over a 24hr period, a safe daily intake of iodine has been estimated to be between 50μg and 1000μg (WHO, 1994). A generally accepted desirable adult intake is 100-300μg/day. These intakes are similar to the recommendations by the Food and Nutrition Board (1989) but slightly different from the recommended daily intake of iodine for different age groups (Table 1) as indicated in the draft WHO/UNICEF/ICCIDD report (1999).

Table 1. The recommended daily intake of iodine for different age groups (WHO/UNICEF/ICCIDD, 1999)

AGE	INTAKE (μg/day)
Infants below 1 year	50
1-6 years	90
7-12 years	120
Adults, > 12years	150
Pregnant and lactating women	200

4.3 DIETARY SOURCES

Iodine does not occur naturally in specific foods (except for marine products). It is present in the soil and is obtained through foods grown on that soil (Hetzel & Pandav, 1994, p.26; WHO, 1994). The availability of iodine and other trace elements in soil and plant systems is a complex problem influenced by various factors; soil type and pH, local geology, type of fertilizers used, source of irrigation, average annual precipitation, crop species and rotation pattern, stage of plant maturity and climatic factors (WHO, 1994). Unlike humans and animals, plant growth, development and production do not depend on iodine instead iodine is

taken up by the plant from the soil and becomes available for human and animal nutrition (Pandav & Rao, 1997, p.17).

Iodine occurs in extremely variable amounts in food and drinking water. Seafood such as clams, lobsters, oysters, sardines, and other salt-water fish are rich sources of iodine (WHO, 1994; Lamberg, 1993). Salt-water fish contain 300 to 3000μg/kg of flesh and are potent sources of this mineral while fresh water fish contain 20 to 40μg/kg but they are still good sources of this mineral. The iodine content of cow milk and eggs is determined by the iodides available in the diet of the animal, and the iodides in vegetables vary according to the amount in the soil in which they grow (Lamberg, 1993; Anderson, 2000, p.139). Iodine content in a specific food however can vary considerably, for example, iodine in codfish has been shown to vary from 12 to 652μg/100g (Rasmussen *et al.*, 1999). Iodine also enters the food chain through the use of iodophors as disinfectants, colouring agents and dough conditioners. These sources add significant iodine to the food supply (Lamberg, 1993; Anderson, 2000, p.139).

The iodine content of the water in wells and lakes gives an idea of the availability of iodine in the soil and this is further reflected in the iodine content of foodstuffs, such as vegetables and animal products coming from that region (Lamberg, 1993; UNICEF, 1998). Sea- food is therefore the richest source because of the high iodine content in the oceans.

4.4 THE SPECTRUM OF IDD

The spectrum of IDD is shown in the four phases of life (Table 2). The most outstanding abnormalities include stillbirths, increased infant and child mortality, growth abnormalities and above all, effects on brain development (Delange, 1994; Cobra *et al.*, 1997; Delange *et al.*, 1997). Whilst iodine deficiency is most commonly assessed by goitre this is as much an indicator as the primary disorder (Hetzel, 1993b, p.18; Lal,

1996). Thus the term iodine deficiency disorders introduced by Dr Hetzel in 1983 has now become accepted (Hetzel, 1993b, p.23). The term includes all the clinical and sub clinical manifestations of iodine deficiency at all life stages (UNICEF, 1995; Pandav & Rao, 1997, p.47; Mallik *et al.*, 1998).

Table 2.The spectrum of IDD (Hetzel, 1989)

STAGE IN LIFE	HEALTH EFFECTS
Foetus	Abortions Stillbirths Congenital abnormalities Increased Prenatal mortality Increased infant mortality Neurological cretinism: -mental deficiency -deaf mutism -spastic diplegia -squint Myxedematous cretinism: -mental deficiency -dwarfism
Neonate	Neonatal goitre Neonatal Hypothyroidism
Child and Adolescence	Goitre Impaired mental function Retarded physical development
Adult	Goitre with complications Hypothyroidism Impaired mental function

4.4.1 Endemic goitre

Endemic goitre is an adaptive disease that develops in response to an insufficient supply of dietary iodine (Delange, 1994; Pandav & Rao, 1994, p.17). Dietary iodine deficiency results in decreased plasma levels of T4 and T3 and a compensatory increase in TSH secretion via a feedback system of the T4 and T3 on the pituitary gland. In an attempt to increase iodine uptake with limited intake, TSH increases thyroidal cell size and cell number and the gland enlarges to form goitre. When this reaches a prevalence of 5 percent of a defined population it is called endemic goitre (Hurrel, 1997). When iodine intake is abnormally low, adequate secretion of thyroid hormones may still be achieved by marked modification of thyroid activity (Delange, 1994; Hetzel, 1994, p.19). This adaptive process includes stimulation of the trapping mechanism as well as of the subsequent steps of the intra-thyroidal metabolism of iodine, leading to preferential synthesis and secretion of T3.

The fundamental mechanism by which the thyroid gland adapts to an insufficient iodine supply is to increase the trapping of iodide due to TSH-independent augmentation of membrane iodide trapping and TSH stimulation of the iodide pump (Brabant *et al.*, 1992; Dumont *et al.*, 1995). This results in the accumulation within the gland of a larger percentage of the ingested exogenous iodide and a more efficient reuse of iodide directly released by the thyroid or generated by the degradation of thyroid hormones (Struder *et al.*, 1974). The absolute uptake of iodide by the thyroid remains normal and the organic iodine content of the thyroid remains within the limits of normal that is 10 to 20mg as long as the iodine intake remains above a threshold of about 50µg/day (Delange, 1994). Below this critical level of iodine intake, in spite of a further increase of thyroid clearance, the absolute uptake of iodide diminishes and the iodine content of the thyroid decreases. Goitre, the visible consequence of

iodine deficiency by public health standards starts to develop usually when the iodine intake is still lower than the physiological requirements. Goitrogenesis therefore is initiated by prolonged hyper-stimulation of the thyroid leading to proliferation of those thyroid cells with greatest growth potential (Studer *et al.*, 1985). Preferential replication of cell with the greatest intrinsic growth potential leads to the development of considerable heterogeneity of structure and function in such glands. Nodularity is the end result together with fibrosis and cystic degeneration.

4.4.2 Endemic cretinism

In severe endemic goitre, an abnormally high number of patients exhibit irreversible anomalies of intellectual and physical development grouped under the general heading of endemic cretinism (Patel *et al.*, 1973; Delange, 1991). The etiopathogenesis of endemic cretinism is only partly understood and information on its pathology is scanty and for this reason the diagnosis of endemic cretinism is descriptive and is made on clinical and epidemiological grounds (Delange, 1994). A study group of Pan American Health Organization defined the condition of endemic cretinism by three major features (Delange *et al.*, 1986):

1. Epidemiology: It is associated with endemic goitre and severe iodine deficiency.
2. Clinical features: These comprise mental deficiency, together with either:
   A. A predominant neurological syndrome including defects of hearing and speech and characteristic disorders of stance and gait of varying degree; or/and
   B. Predominant hypothyroidism and stunted growth.
3. Prevention: In areas in which iodine deficiency has been adequately corrected, endemic cretinism has been prevented.

There are two types of endemic cretinism. The first type is marked by dominant neurological disorders (neurological cretinism). The second

type is, marked by signs of severe thyroid insufficiency (myxedematous cretinism) (Delange, 1994).

4.4.2.1 Neurological cretinism

The endemic cretins (as found for example in Nepal) are extremely mentally retarded and most of them are reduced to a vegetative existence (Delange, 1994; WHO/UNICEF/ICCIDD, 1994). Almost all are deaf mutes and are afflicted with the following neurological defects: (a) Impaired voluntary motor activity, usually involving paresis or paralysis of pyramidal origin, chiefly in the lower limbs, with hypertonia, clonus, and plantar cutaneous reflexes in extension and occasionally extrapyramidal signs, (b) spastic or ataxic gait (in the severest cases, walking or even standing is impossible) and (c) strabismus. The prevalence of goitre in neurological cretins is as high as non-cretin population of the area and they are clinically euthyroid. Thyroid function is usually normal but can indicate sub-clinical hypothyroidism with elevated basal TSH or exaggerated TSH response to Thyrotophin releasing hormone (TRH) (Shenkman *et al*, 1973; WHO/ UNICEF/ICCIDD, 1994).

4.4.2.2 Myxedematous cretinism

The typical myxedematous cretins (as seen for example in Zaire) show less mental retardation than the neurological cretins and they are often capable of performing simple manual tasks (Vanderpas *et al.*, 1990; WHO/ UNICEF/ICCIDD, 1994). All exhibit major clinical symptoms of long-standing hypothyroidism: dwafism, myxedema, dry skin, sparseness of hair and nails, retarded sexual development, and retarded maturation of body proportions and of naso-orbital configuration (Delange, 1994). The cretins occasionally exhibit neurological signs including spasticity of the lower limbs, jerky movements and Babinski sign, as observed in long-standing unrecognized sporadic congenital hypothyroidism. The prevalence of goitre in the myxedematous cretins is much lower than in

the non-cretin population. Many of them have non-palpable thyroid tissue (Delange 1994; WHO/UNICEF/ICCIDD, 1994). Several observations clearly demonstrate that myxedematous endemic cretinism results from severe thyroid failure occurring during foetal or early postnatal life. Chinese data have indicated that hypothyroidism is present in human foetuses from the fourth month of gestation in regions of severe iodine deficiency and myxedematous endemic cretinism.

4.4.3 IDD In different age groups

4.4.3.1 Iodine deficiency in the foetus

Iodine deficiency in the foetus is the result of iodine deficiency in the mother. This condition is associated with greater incidence of stillbirths, abortions and congenital abnormalities (McMichael *et al.*, 1980, p.16; Hetzel, 1994, p.31). Another major effect of foetal iodine deficiency is endemic cretinism. Its commonest form is the neurological type, which is not reversed by administration of iodine or thyroid hormones (Hurrel, 1997) and is characterized by mental deficiency, deaf mutism and spastic diplegia (Pharoah *et al.*, 1971; Lazarus & Hall, 1988). In mild iodine deficiency, the foetus can compensate when the maternal hypothyroxinaemia is not severe, but with the declining maternal T4 level in severe iodine deficiency foetal hypothyroidism ensues with its attendant irreversible neurological deficits (neurological cretinism) (Thilly *et al.*, 1980; Eastman & Phillips, 1988; Hetzel, 1994, p.14). This condition occurs with an iodine intake of below 25μg per day in contrast to a normal intake of 100 to 150μg per day (Hetzel, 1993a, p.542).

In 1966, a study in Papua New Guinea revealed that the injection of iodised oil given prior to pregnancy would prevent the occurrence of the neurological syndrome of endemic cretinism in the infant (Pharoah *et al.*, 1971). The occurrence of the syndrome in those who were pregnant at the time of injection indicated that the damage probably occurred during

the first half of pregnancy. The controlled trial with iodised oil also revealed a significant reduction in recorded foetal and neonatal deaths in the treated group.

Further data from the Papua New Guinea indicate a relationship between the level of maternal T4 and the outcome of pregnancies both current and in the recent past, including mortality and the occurrence of cretinism (Pharoah, 1993). There were proportionally more perinatal deaths and cretins, among the offspring of women who showed the lowest levels of serum T4. Several observations clearly demonstrated that myxedematous endemic cretinism, results from severe thyroid failure occurring during foetal or early postnatal life. Chinese data have indicated that hypothyroidism is present in human foetuses from the fourth month of gestation in regions of severe iodine deficiency and myxedematous endemic cretinism is highly prevalent (Delange, 1994).

4.4.3.2 Iodine deficiency in the newborn

In the neonate, iodine deficiency leads to increased perinatal and infant mortality (Hurrel, 1997). An increased perinatal mortality due to iodine deficiency has been shown in Zaire from the result of a controlled trial of iodised oil injections given during the latter half of pregnancy, alternatively with a control injection (Hetzel, 1993a, p.541). There was also a substantial fall in infant mortality with improved birth weight following the iodised oil injection. Low birth weight is generally associated with a higher rate of congenital abnormalities and a higher mortality risk through childhood (Hetzel, 1993a, p.542; Hetzel & Pandav, 1994, p.16).

Serum TSH levels are an excellent indicator for hypothyroidism in neonates (Hetzel & Pandav, 1994, p.23). This condition is associated with a defect in the production of thyroid hormones due to the absence of the thyroid, a small, misplaced thyroid or a defect in the biochemical machinery in the thyroid. Elevated serum TSH in the neonates therefore

indicate insufficient supply of thyroid hormones to the developing brain (Delange, 1998). The importance of the state of thyroid function in the neonate relates to the fact that at birth the brain of the human infant has only reached about one-third of its full size and continues to grow rapidly until the end of the second year of life (Hetzel & Pandav, 1994, p.18).

Thyroid hormones in the neonate play a critical role in growth and maturation of all organs, especially the brain. Consequently, hypothyroidism during foetal and postnatal life not only affects postnatal growth but also brain development, resulting in irreversible mental retardation (Fisher *et al.*, 1979; Delange, 1998). If there is adequate iodine intake, neonatal hypothyroidism occurs at the rate of 1 in 4, 000 births (0.025%) and if iodine intake is inadequate then the rate may increase to 1 percent or even up to 10 percent births which indicate a massive threat to brain development (Stanbury & Pinchera, 1994, p.76).

Neonatal thyroid screening using serum TSH as the primary screening test detects not only permanent sporadic congenital hypothyroidism, but also compensated or transient primary hypothyroidism, whose incidence can be as high as 1 in 10 neonates and whose main cause is iodine deficiency (Delange, 1998). In developing countries there is a much higher rate of neonatal hypothyroidism shown in blood taken from the umbilical vein just after birth. For example neonatal observations in Zaire showed rates of 10 percent of chemical hypothyroidism (Ermans *et al.*, 1980). The hypothyroidism persists into infancy and childhood if the deficiency is not corrected, and retardation of physical and mental development results (Hetzel *et al.*, 1990).

4.4.3.3 Iodine deficiency in childhood and in adolescence

Iodine deficiency in childhood and adolescence is characteristically associated with endemic goitre. The prevalence increases with age, reaching a maximum after the first decade and studies have shown that

girls have a higher prevalence than boys (Delange, 1994). The results from endemic goitre study in Greece (Koutras *et al.*, 1973) suggested that children living in areas with endemic goitre, present suggestive signs of sub-optimal nutritional status and delayed growth compared with a control group. From the study in Eastern Caprivi, Namibia (Jooste *et al.*, 1992) there was an overall goitre prevalence of 34.5 percent in school children aged 6 to 18 years and anthropometrical indicators of nutritional status revealed both underweight and stunting in these children. Pongpaew *et al.* (1998) indicated an increase in the weight and height of school children in an endemic area of iodine deficiency disorders after one year of iodine supplementation.

Areas with severe endemic goitre and endemic cretinism often contain individuals who appear superficially normal but have mild mental retardation or minor motor disabilities on closer examination. This observation suggested the possibility that a large segment of these populations may have neuromotor impairment of a degree which is little noted by local population, but which might be significant in the context of the social and economic development of the community. Dodge *et al.* (as cited by Hetzel *et al.*, 1987, p.43) were the first to show that neuromotor developmental lag in school children in a highly endemic region in Andean Ecuador. They found that there was no bimodality of the scores in the children of the villages, that is the scores varied continuously from those of the obvious cretins to those who appeared to be normal and who were performing well in school. More recent long-term studies from the same region have shown that older children, even when accepted for school had higher dropout rate, poorer performance, higher failure rates, and poorer scores on tests of psychomotor performance if their mothers had not received iodine (Hetzel, 1987, p.24).

There is increasing evidence of impaired mental function in apparently normal children living in iodine deficient areas (Hetzel, 1993b, p.19). Euthyroid schoolchildren born and living in iodine deficient environments

were reported to exhibit subtle or even overt neuropsycho-intellectual deficits when compared with controls from non-iodine deficient environments, living in the same ethnic, demographic, nutritional and socio-economic system. Low verbal Intelligence Quotient (IQ), perception and attentive function have also been reported with moderate iodine deficiency (Delange, 1994). Hetzel (1993b, p.27) indicated that low maternal thyroxine levels during pregnancy significantly affected the children's dexterity even when tested at the age of 10 to 12 years. The onset of these effects is often insidious and most are irreversible after the second year of life (Hetzel & Maberly, 1993).

Studies on school children living in iodine deficient areas from a number of countries indicate impaired school performance and Intelligence Quotients (IQs), in comparison to similar groups from iodine replete areas (Lamberg, 1993; Hetzel, 1993a, p.537). A comprehensive review of the relation between iodine deficiency and intellectual performance outcomes in school children concludes that children who grow up in an iodine deficient environment accumulate a cognitive deficit of at least 10 IQ points in comparison to their peers from iodine sufficient areas (WHO, 1995; Shrestha & West, 1996).

Observations by Bleichrodt *et al.* (1987, p.69) indicated lower scores in measured mental and perceptional development in children in a severely iodine deficient area in Spain compared with a control group carefully matched by socio-economic status and educational level. Recent studies in Indonesia and in an iodine deficient area in Spain, using a wide range of psychological tests, have shown that mental development of children from iodine deficient areas lags behind that of children from iodine replete areas (Pardede *et al.*, 1998). The difference in psychomotor development becomes apparent after the age of two and a half years. It was also found in Indonesia that cognitive performance of the school children had a direct relationship with iodine status (Pardede *et al.*, 1998). Similar findings were observed in Kwazulu Natal (South Africa) where goitrous

subjects scored on average 5.2 percent lower than those without goitre in their Zulu exam papers (Benade *et al.*, 1997).

In China, studies indicated that lower intelligence quotient scores resulted due to nerve deafness, which was detected by audiometry and the presence of abnormal neurological signs similar to the pattern observed more obviously in overt neurological cretinism (Boyages *et al.*, 1989). These studies confirm the large dimension of the brain component in IDD.

4.4.3.4 Iodine deficiency in adults

A common effect of iodine deficiency in adults is endemic goitre. Characteristically, there is an absence of classic clinical hypothyroidism in adults with endemic goitre (Patel *et al.*, 1973; Hetzel, 1987, p.549). Biochemical evidence of hypothyroidism with reduced T4 levels is however common. This is often accompanied by normal T3 levels and raised TSH levels.

A high degree of apathy has been noted in populations living in iodine deficient area in Northern India and this may even affect domestic animals such as dogs (Hetzel, 1994, p.9). It is also apparent that reduced mental function due to brain hypothyroidism is widely prevalent in iodine deficient communities and has an effect on their capacity for initiative and decision-making (Hetzel & Pandav, 1994, p.34). This indicates that iodine deficiency can be a major obstacle to the human and social development of communities living in an iodine deficient environment.

4.4.3.5 Iodine induced hyperthyroidism

In humans it has been reported that an intake exceeding 2000 to 3000µg of iodine per day is potentially harmful (Pandav & Rao, 1997, p.49). The effects of high iodine intake on thyroid function are variable and depend chiefly on the health of the thyroid gland (WHO, 1994; Lee *et al.*, 1999).

The side effects include iodine induced hyperthyroidism (IIH), iodine induced hypothyroidism, iodine induced autoimmunity both of the Hashimoto and of the Graves types, and an increase in the incidence of papillary cancers (Koutras, 1996). Skin rashes and acne have also occasionally been attributed to iodised salt but such reports are extremely rare and these conditions are unlikely to occur following salt iodisation (WHO, 1994). Anderson (2000, p.140) states that iodine intake has a rather wide margin of safety. However in some cases goitre is seen as a possible consequence of long-term iodine intake well in excess of physiological need.

In the normal, healthy thyroid, high levels of iodine intake have little lasting effect even when loads are large, that is 1000 to 2000µg per day (Lee *et al.*, 1999). Under such circumstances the normal thyroid temporarily ceases production of thyroid hormone. This shutdown of hormone production is called the Wolff-Chaikoff effect. The normal thyroid ceases thyroid hormone synthesis until the thyroid tissue can adapt to the high intercellular level of iodine, then the production of thyroid hormone resumes to normal in the face of the new, higher level of iodine intake. Thyroid functions remain normal in this population. This process is known as "escape from the Wolff-Chaikoff effect".

In patients with thyroiditis, most typically caused by Graves' or Hashimoto's disease, the diseased thyroid stops producing thyroid hormone when exposed to elevated intakes for a variable length of time and hypothyroidism may occur (Lee *et al.*, 1999). IIH or Jod-Basedow Thyrotoxicosis, occurs in patients with thyroid nodules that are "autonomous" or "overactive" (Skare & Frey, 1980; Lee *et al.*, 1999). Autonomous nodules produce thyroid hormone in direct correlation with iodine intake without regard to thyroid hormone levels. These nodules produce excess thyroid hormone because they lack feed back controls and do not shut down like normal thyroid tissue does in the face of high iodine intakes.

It was concluded in Zaire that IIH associated with iodine prophylaxis in developing countries is probably an important and underestimated problem that is difficult to recognize clinically and may be life-threatening (Communique, 1995; Bourdoux *et al.*, 1996). IIH may cause elevation in basal heart rate, anatomical changes in heart muscle, and demineralisation of bone (Stanbury *et al.*, 1998). In Britain mortality from IIH peaked in the decade 1931 to 1940 and both the mortality and incidence of thyrotoxicosis due to toxic nodular goitre have remained highest in those areas which once had endemic goitre (Barker & Phillips 1984; Phillips, 1997).

IIH occurs when persons are exposed to an incremental increase in iodine intake that may be from iodine supplements given prophylactically for iodine deficiency or when administered in various iodine-containing pharmaceuticals (Phillips, 1997). There are many reports however, of successful use of iodised salt prophylactically and has been used by a normal population as a purifier without mention of IIH. The frequency with which IIH occurs depends on a number of factors (Stanbury *et al.*, 1998). They include the severity of iodine deficiency that existed before prophylactic iodine was introduced, the magnitude of the incremental rise in iodine intake, the frequency of autonomous elements in the thyroid, the age groups examined, the skills and instruments used in ascertainment and when or at what intervals the disorder is investigated.

IIH is an IDD, which may occur primarily in older people with long standing nodular goitre, in population that have been long exposed to iodine deficiency and where severely iodine deficient populations increase their iodine intake (Bartalena *et al*, 1996; Todd & Dunn, 1998; Stanbury *et al.*, 1998), even when total amount is within the usually accepted range of 100 to 200μg/day and is not recognized to be a problem in younger subjects (WHO, 1996). It may develop in persons with clinically normal

thyroid glands when they are exposed to large amounts of iodide and may return to normal when the iodine is withdrawn (Stanbury *et al.*, 1998).

Administration of ordinary amounts of iodine has also been reported to induce hyperthyroidism in people with nodular thyroids, and in other individuals who have no apparent underlying disease. However, these are transient phenomena, which cease after correction of iodine deficiency (WHO, 1994) and in any case the benefits of iodisation programs far outweigh the risks provided they are implemented and monitored carefully (Koutras, 1996). For example in Switzerland, iodine content of salt was increased from 7.5 to 15mg/kg and this raised mean urinary iodine excretion from 90 to 150µg/g creatinine (Baltisberger *et al.*, 1995). Except for a 27 percent rise in the first year of the salt iodisation concentration, the total incidence of hyperthyroidism declined steadily to reach 44 percent of the control level in 1988 to 1989 and this was due to a decrease mostly of toxic nodular goitre.

4.5 THE MAGNITUDE OF THE IDD PROBLEM

The iceberg effect of IDD as well as the fact that iodine deficiency is a public health problem world wide including Africa and Lesotho will be shown.

4.5.1 The IDD iceberg

IDD can be seen as an "iceberg" (Figure 3) of effects in a community or population (Hetzel & Pandav, 1994, p.36). In a severely iodine deficient area, cretinism with a prevalence of 1 to 10 percent 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. This iceberg means that in a community with the prevalence of 1 to 10 percent of cretinism there will be 5 to 30 percent suffering from lesser degrees of brain damage (Hetzel, 1989, p.7). Only

rough estimates are available, suggesting that up to 70 percent in a severely iodine deficient area may be suffering from lethargy indicating some degree of cerebral hypothyroidism (Dunn, 1996). Thus the typical cretin of severe iodine deficiency is one end of a spectrum of retardation that extends to mild and subtle depression of mental ability at the other end along with assorted deficits in hearing, learning and reproductive outcome.

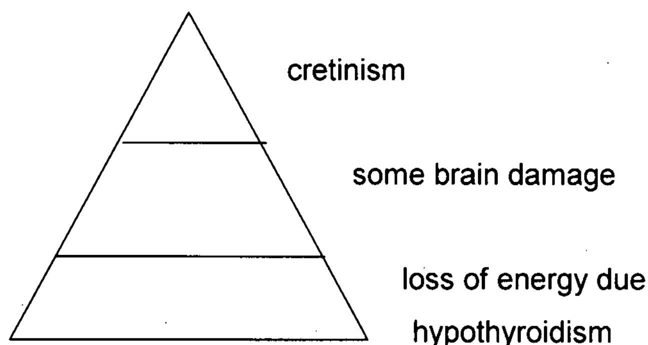

Figure 3. The IDD iceberg effect (Hetzel, 1989).

4.5.2 IDD as a global problem

According to Word Health Organization Report (1994), 15 percent of the world population is affected by IDD. Of the 169 countries in the world for which data are available 118 countries are known to have a total goitre rate of more than 5 percent (Pandav & Rao, 1997, p.29). A recent WHO/UNICEF/ICCIDD report (1996), states that at-least 1,570 billion people (or 29% of the world's population) live in areas of iodine deficiency and need some form of iodine supplementation. It is also estimated that the world incidence of goitre is approximately 200 million (Anderson, 2000, p.160). The rate is higher in women than men and it is higher for older than younger groups. A map presented by WHO (1993) gives the recent global goitre prevalence information (Appendix 1).

4.5.3 IDD in Africa

In Chad, a nationwide sample survey indicated goitre prevalence of 63 percent and prevalence of cretinism varied between 0 and 1.2 percent in people between 10 and 20 years (Wyss *et al.*, 1996). In Guinea, West Africa, 70 percent of adults and 55 percent of school children were affected and endemic cretinism was noted in about 2 percent goitrous persons (Konde *et al.*, 1994). The Eastern, Central and Southern African countries forming the Sub-regional Working Group on control of IDD are Botswana, Ethiopia, Kenya, South Africa, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe. These countries are of varying sizes and populations but with the exception of Mauritius and Seychelles, IDD is a problem of public health significance in all of them, but with varying degrees of severity (Kavishe, 1994; p68). A map presented by WHO (1993), gives the recent goitre prevalence information in Africa (Appendix 5).

In South Africa some numerous reports on endemic goitre were cited, concerning eight regions in South Africa and four in adjacent territories (Walker, 1995). Unfortunately most reports were not published in journals. The frequency of thyroid disorders at the Jane Memorial Mission Hospital in Sekhukhuneland indicated that mild goitre was probably endemic among the inhabitants before 1972 (Edginton *et al.*, 1972). During 1976 and 1977, approximately 10 percent of people attending the clinic at Masebuko in Kwazulu had grade 1 and grade 2 goitres (Roodt & Kloppers, 1980). Recent studies also indicate moderate to severe prevalence of IDD in South Africa where goitre prevalence in the range 20 to 29.9 percent and urinary iodine level in the range 20 to 49μg/l were observed in a cross-sectional community based survey in Ndunakazi, a

rural area at Kwazulu-Natal (Benade *et al.*, 1997). In the Langkloof area the prevalence of goitre varied from 14.3 to 30.2 percent in four communities (Jooste *et al.*, 1997). The total goitre prevalence by palpation ranged from 72.1 to 78.3 percent and median urinary iodine concentration was 15µg/l in the Shongwe district (Kalk *et al.*, 1997). A more recent study in the Northern Cape province indicated endemic goitre ranging from 5 to 29 percent and an adequate median urinary iodine concentration of more than 158µg/l in six towns (Jooste *et al.*, 1999). It was suggested that the high concentration of fluoride in the drinking water of this area might have been responsible for the goitres.

4.5.4 IDD in Lesotho

In Lesotho goitre surveys have been conducted as early as 1960. A national study conducted by Munoz and Anderson (1960) showed the total goitre rate of 41 percent and visible goitre rate of 14 percent in school children aged 6 to 13 years. In 1962 a study conducted in one district Qachas' Nek indicated a total goitre rate of 27.8 percent in school children (Salhis, 1962). The multistage cluster survey conducted in the Mountain and Senqu river valley zones indicated TGR of 46.5 percent and VGR of 22.5 percent in clinic attendants aged 12 years and over (Mpeta, 1987). The second national study was conducted by the Nyapisi (1988) and indicated a prevalence rate of 42 percent in women of childbearing age and 21 percent in school children between the age of 6 and 13 years. The median urinary iodine concentrations in the Mountains and Lowlands were 35µg/l and 55µg/l respectively.

The 1993 National Micronutrient survey conducted in four zones; Mountain (Highlands), Sengu River Valley, Foothills and the Lowlands indicated the TGR of 39.4 percent and the VGR of 14.6 percent in women of childbearing age (Wolde-Gebriel, 1993). The total goitre rate in school children aged 6 to 16 years was 42.5 percent and visible goitre rate was 15.3 percent. Goitre was more prevalent in the Mountain zone than the

rest of the zones. In this survey the soil and water collected in various places were found not to contain iodine. A recent study conducted at Mohale Dam catchment area indicated the prevalence of 17.5 percent in children between age 10 and 14 and the urinary iodine excretion of 13μg/l (Jooste *et al.*, 1997).

5. DETECTION OF IODINE DEFICIENCY

Measurement of the extent of IDD in a population indicates the extent and severity of the problem (Dunn & Van Der Haar, 1990, p.26; Stanbury & Pinchera, 1994, p.14). It also indicates progress in the elimination of IDD. Measurement of IDD therefore provides key information in deciding whether a program is required for IDD elimination and once having initiated such a program measurement is required to demonstrate its effectiveness (Stanbury & Pinchera, 1994, p.19).

The first question to ask is whether iodine deficiency exists in a particular region or population and if so, how severe it is (Dunn & Van Der Haar, 1990, p.31). Usually some previous information will be available. For example health workers may have noted that many people from a certain area have visible goitre. Often the likelihood of iodine deficiency in a given region can be predicted from knowledge of its geographical location. Thus iodine deficiency should be suspected in an area surrounded by other iodine deficient regions, or in remote areas, especially those with high mountains.

Selecting the optimal group or groups for an IDD survey depends on a number of considerations, including their vulnerability, representativeness, accessibility and potential usefulness for surveillance of multiple health problems. A variety of target groups including neonates, infants, preschool-age children, school-age children and certain groups of adults might serve as the focus for IDD surveillance (WHO, 1994). According to

WHO (1993), adults do not reliably reflect the present iodine status in a population due to the following reasons:

- Preformed nodules or goitres may have occurred in childhood or early adolescence;
- Adults are not suitable for follow up studies after iodine supplementation, since many adult goitres will only partly decrease in size;
- After long-standing iodine deficiency, serum TSH levels fall or become suppressed due to functional autonomy, that is, latent or overt thyrotoxicosis. Following iodine supplementation, TSH normalizes in only a fraction of the adult population.

The thyroid glands of preschool children are too small for accurate determination of the size of the gland by palpation. For this reason they are not an appropriate group for assessing IDD in a community. School-age children are an especially useful population group for the assessment of IDD, because of their physiological vulnerability and their accessibility through schools (Dunn & Van der Haar, 1990, p.14; WHO, 1993; WHO, 1994). Furthermore, the measurement of goitre in school age children is important for public health considerations as this group effectively reflects the current status of IDD in the general population, as well as the extent to which IDD control measures have had an impact (WHO, 1993; Dunn, 1996).

Equipped with an understanding of the factors which influence the distribution of IDD, the selection of indicators for use in the assessment of IDD in a population should include consideration of; social acceptance of the assessment technique, technical feasibility, costs and performance (WHO, 1993; WHO, 1994). There are two types of indicators; outcome indicators that provide a measure of IDD status, and process indicators that measure the condition or progress in implementing an IDD control program (WHO/UNICEF/ICCIDD, 1994). Both clinical and biochemical

assessments are outcome indicators and salt iodisation level assessment is a process indicator.

5.1 BIOCHEMICAL INDICATORS

The available biochemical indicators include urinary iodine, thyroid stimulating hormone, thyroid hormones and thyroglobulin.

5.1.1 Urinary iodine

The concentration of iodine in urine is currently the most widely used biochemical marker of iodine deficiency, for several reasons (Dunn *et al.*, 1993; p8; WHO/UNICEF/WHO, 1994; May & May, 1998). Most of the body's iodine is excreted in the urine, usually over 90 percent thus, the iodine level in urine reflects the subject's intake. Urine is easy to obtain in the field, in contrast to serum. Iodine in urine is stable and can withstand collection and transport under field conditions. Finally, measurement of urinary iodine has usually been technically simpler and cheaper than other biochemical markers, such as serum level of thyroid hormones or TSH, or procedures with radioiodine.

Since an individual's level of urinary iodine varies daily and even during a given day, data can be used only for making a population-based estimate (Dunn & Van Der Haar, 1990, p32). Experience has shown that the iodine concentration in early morning urine specimens (casual urine samples) provides an adequate assessment of a population's iodine status therefore 24 hour samples are not necessary (WHO, 1994) however 24hr urinary iodine excretion remains the recommended measure for individual iodine status (Thompson *et al.*, 1997). Reliance on concentration alone raises the obvious question of whether natural variations (day to day and within day variations) in urinary volume (through dehydration, increased fluid consumption or dilution) will provide misleading estimate of actual urinary iodine (Dunn *et al.*, 1993, p.9;

Rasmussen *et al.*, 1999). Clearly such variation in volume exists and for this reason it is recommended that samples be obtained from at-least 40 subjects to determine the mean concentration of urinary iodine in a given region (Dunn & Van Der Haar, 1990, p.43; Dunn *et al.*, 1993, p.13). Urinary iodine values from populations are not normally distributed, so it is recommended that the median value be used for interpretation of the data not the mean (WHO/UNICEF/ICCIDD, 1994; May & May, 1998).

Two general approaches have been used to relate the iodine content of a casual urine sample to the 24hr value (Dunn & Van Der Haar, 1990, p.39). One approach relates urinary iodine to urinary creatinine, a chemical substance, which the body excretes daily in fairly constant amounts. Using this approach, one can measure both the iodine and creatinine in a casual urine sample, and express the results as a ratio, μg iodine per gram creatinine. The other approach is to simply measure the concentration of iodine in the urine as μg iodine per litre of urine.

More recently Bourdoux and others have recommended that the urinary iodine be expressed as a concentration, in μg/dl, rather than relating it to creatinine based on the fact that creatinine excretion can vary considerably among population groups and among individual, as well as in the same individual at different times (Hetzel, 1993a, p.551; Bourdoux *et al.*, 1993; Thomson *et al.*, 1997). Also lower creatinine excretions frequently occur in areas of malnutrition, which are the areas most likely to harbor IDD. Relating urinary iodine to creatinine is cumbersome, expensive and unnecessary therefore it has been found preferable to express results per litre of urine (WHO/UNICEF/ICCIDD, 1994). The use of the iodine/creatinine ratio in casual urine samples was found to be a usable measure of iodine status if corrected for age and sex in Denmark (Rasmussen *et al.*, 1999).

The advantages of assessment are that the method is entirely objective, it is non-invasive and it provides information on the one factor that can be

addressed directly, that is, iodine supply to the individual (Dunn & Van Der Haar, 1990, p.27). The excretion of iodine indicates the recent but not precisely the immediate intake of iodine (Stanbury & Pinchera, 1994, p.23; Pardede *et al.*, 1998). Acceptability is very high and spot urine specimens are easy to obtain. Urinary iodine assay methods are not difficult to learn or use, but meticulous attention is required to avoid contamination with iodine at all stages (WHO, 1994; Pardede *et al.*, 1998). The recommended methods are able to detect urinary iodine levels as low as 5 to 20μg/l with a coefficient of variation under 10 percent. Laboratory techniques require thorough training and standardisation.

There is great diversity in available urinary iodine methods with respect to cost, technical sophistication, sample processing capacity and performance (Binnerts & Das, 1974; Dunn *et al.*, 1993, p.18). Techniques that avoid problems of having to destroy potential interfering substances, such as neutron-activation analysis or inductively coupled plasma-mass spectrometry (ICP-MS), are generally considered gold standard methods for urinary iodine analysis but are unrealistic for widespread use because of high cost and degree of sophistication.

For public health purposes, especially in developing countries, there is a need for relatively quick, simple and cost-effective methods for determining urinary iodine concentrations in reasonable numbers of samples (May *et al.*, 1997; Rendl *et al.*, 1998). Many different urinary iodine methods are available, ranging from technically sophisticated/automated techniques, to simple manual techniques with limited instrumentation requirements (May & May, 1998). The latter are more suitable for public health purposes, as part of overall national IDD elimination programmes. Various techniques have been compared and each has its own advantages and limitations (Pino *et al.*, 1996). The Sandell-Kolthoff reaction with some prior step involving ashing or digestion is usually the most practical approach for laboratory

determination of urinary iodine (Dunn *et al.*, 1993, p.23; May & May, 1998).

According to WHO/UNICEF/ICCIDD, the severity of iodine deficiency using the median urinary iodine concentration is as follows;

Median value (μg/l)	Severity of IDD
<20	Severe IDD
20-49	Moderate IDD
50-99	Mild IDD
100-199	Adequate iodine nutrition
200-300	More than adequate iodine intake, may pose an increased risk of IIH
>300	Excessive iodine intake

5.1.2 Thyroid Stimulating Hormone (TSH)

The fall in the level of T4 leads to an increase in TSH output from the pituitary (Dunn & Van Der Haar, 1990, p.41), thus serum or whole blood TSH levels directly reflect the availability and adequacy of thyroid hormones (Hetzel, 1993a, p.548). TSH level is the best diagnostic test for determining hypothyroidism. Elevated serum TSH in the neonate indicates insufficient supply of thyroid hormones to the developing brain and therefore constitutes the only indicator that allows prediction of possible impairment of mental development at a population level which is the main consequence of iodine deficiency (Delange, 1998). It is of considerable concern because this indicates an inadequate thyroid hormone level during the crucial stage of brain development (WHO, 1994). It has demonstrated its validity and usefulness and is largely implemented in countries with mild degrees of iodine deficiency (Delange, 1998). It is however still insufficiently available in countries with moderate

and especially severe degrees of iodine deficiency, essentially because of a lack of resources and infrastructure.

Blood specimens may be obtained from pregnant women or school-age children (WHO/UNICEF/ICCIDD, 1994). Further study of TSH distributions among these older subjects is needed to improve understanding of the specificity of their relationship to iodine deficiency. This is because elevation of TSH values in individuals is associated with all causes of primary hypothyroidism including goitrogen ingestion, congenital hypothyroidism and autoimmune thyroiditis. It is therefore concluded that TSH levels are an excellent indicator for hypothyroidism in neonates but their specificity in older groups is less certain. Thus reference data for TSH are available only among neonates.

Speculation on one of the factors involved had been done on the basis of the comparison of the iodine stores of the thyroid and of the needs of T4 in adults and neonates (Delange, 1998). In Canada, Belgium and Germany turnover rate of the iodine stores required in order to face the requirements of thyroid hormones, which is about 1 percent per day in adults was found to be higher in neonates; 17 times higher than normal adults (in Canada), 62 times higher than adults in conditions of mild iodine deficiency (in Belgium) and 125 times higher than adults in conditions of severe iodine deficiency (in Germany). In these conditions it is therefore expected that the degree of stimulation of the thyroid by TSH have to be markedly increased.

There are however some disadvantages with this approach. This method requires sophisticated laboratory backup and an organized program of sample collection (Stanbury & Pinchera, 1994, p.43). Also any program that involves blood samples carries the risk of unclean needles and the implied risk of hepatitis or the acquired immune deficiency syndrome (AIDS).

According to WHO/UNICEF/ICCIDD (1994) the severity of public health problem using TSH>5mU/l whole blood for neonates is as follows:

Prevalence	Severity of IDD
3.0-19.9%	mild
20.0-39.9%	moderate
>/= 40%	severe

5.1.3 Thyroid hormones (T4 and T3)

The basic effect of the iodine deficiency is to interfere with the production of thyroid hormones (Hetzel & Pandav, 1994, p.24). In severe endemic goitre, there is an inverse relationship between serum T4 and TSH but this correlation is not found for serum T3, which is the most active thyroid hormone. This is explained by the fact that the direct effect of T4 on TSH suppression, results from intra-pituitary T4 to T3 conversion and the subsequent binding of T3 to the nucleus of the thyrotropes. In other tissues, the largest part of intracellular T3 originates from circulating T3. These findings account for the observation in endemic goitre that normal serum T3 levels enable a patient to maintain an overall euthyroid status, but pituitary stimulation persists as long as the serum T4 level is depressed (Hetzel, 1993, p.549; Delange, 1994). In less severe goitre endemias, serum T4 and T3 levels are only slightly modified or even remain normal (Delange, 1994; Dumont *et al.*, 1995).

The lower output from the thyroid leads to a fall in the blood level of T4 but some increase in T3 preferentially in iodine deficiency. In regions of endemic goitre, the measurement of the amount of hormone in the blood might be the ultimate tool for measuring IDD (Stanbury & Pinchera, 1994, p.46). If iodine is given prophylactically to a community there is generally a net rise in mean serum T4 concentration. This presumably indicates that the population was deficient in iodine, but most often this change occurs within the accepted limits of normal, and few individuals have

values below the accepted lower limit of normal. Thus, from the results of a survey, because the limits of normal are so wide, it would be quite impossible to be certain from measurement of T4 alone, that IDD or a need for iodine is present. Serum concentrations of T3 are even less definitive in this regard.

5.1.4 Thyroglobulin

The fall in the level of T4 also leads to increased turnover associated with hyperplasia and hypertrophy (Hetzel, 1989, p.5). This leads to an enhanced turnover of thyroid cells, which release Thyroglobulin (Tg) into the serum. Tg in serum changes inversely with iodine intake in all age groups (WHO, 1994). The thyroid gland leaks Tg into the blood at a rate roughly dependent on its size. Recent studies have indicated that measurement in serum can grossly mirror the size of the thyroid in regions where IDD is found (Stanbury & Pinchera, 1994, p.39). Increased concentrations of serum Tg have been found in goitrous subjects, and especially in those with larger goitres. This reflects to some extent the degree of chronic thyroid stimulation by TSH and also related to the development of autonomous thyroid function.

The advantages of a Tg assay are its objectivity and reliability. It has the disadvantages that it requires invasion (a blood sample), and that the measurement, being a radio-immunoassay, necessitates special laboratory expertise, special equipment, and a supply of the radio-labelled antigen. It appears to be a promising and potentially useful indicator of IDD, but has yet not been thoroughly validated for epidemiological assessment (Stanbury & Pinchera, 1994, p.41; WHO, 1994).

According to WHO (1994), the severity of public health problem using median Tg (ng/ml serum) for children and adults is as follows:

Median Tg (ng/ml serum)	**Severity of IDD**
10.0-19.9	mild
20.0-39.9	moderate
>/=40.0	severe

Laboratory methods, exists for measuring blood levels of the major thyroid hormones. While giving an accurate assessment, they have the serious disadvantages of being expensive, unavailable in many developing countries, requiring the collection of blood samples and training in laboratory techniques (Dunn & Van Der Haar, 1990, p.23). It is essential that sterile equipment be used. Standard procedures for handling blood products or objects contaminated with blood should be followed (WHO/UNICEF/ICCIDD, 1994).

5.2 CLINICAL INDICATORS

Clinical indicators include thyroid size, cretinism and radioiodine uptake.

5.2.1 Thyroid size

Goitre is usually the most obvious sign of iodine deficiency (Dunn & Van Der Haar, 1990, p.28). The size of the thyroid gland changes inversely in response to alterations in iodine intake. The traditional method for determining thyroid size is inspection and palpation (WHO/UNICEF/ICCIDD, 1994). Ultrasonography provides a more precise and objective method for determination of thyroid size.

5.2.1.1 Inspection and Palpation

Inspection depends on the visual examination of the thyroid (Demaeyer *et al.*, 1979, p.46). It is recommended that a thyroid gland be classified as positive for goitre only when it is 4 to 5 times larger than the normal size when the neck is in the normal position. When the neck is short or the muscles are well developed, inspection alone may fail to reveal a gland that is already 4 to 5 times enlarged. On the other hand, in persons with very thin necks the lobes of the gland can be readily seen and may give impression of a visible goitre even though the thyroid is not 4 to 5 times its normal size. Nodular glands that would be unnoticed on visual examination of the neck are frequently discovered by palpation. It is therefore recommended that both inspection and palpation be used in carrying out goitre surveys.

Palpation of the thyroid size has been the standard technique for measuring endemic goitre (Stanbury & Pinchera, 1994, p.43). Children and adults are examined while standing with the head and neck first in a vertical position and then in an extended position (Demaeyer *et al.*, 1979, p.49). The examiner inspects the thyroid area and without delay uses both thumbs to palpate very gently the full extent of the lobes and the isthmus. It is advisable to ask the patient to relax the neck muscles by throwing the head slightly downwards and it may be helpful to get him to swallow several times. For the most accurate and reliable clinical appraisal of patients, most physicians advise examination from behind, using the forefingers for the palpation of the thyroid gland, but for general survey work it is more convenient to adopt a position in which visual inspection and palpation can be carried out almost simultaneously without requiring the patient to turn around. Usually a thyroid gland whose lateral lobes have a volume greater than the terminal phalanx of the thumb of the person being examined will be considered goitrous.

Palpation can be easily applied in the field and requires no specialized equipment and the examiners need not be medical professionals, but they should be trained and initially supervised by other examiners with

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experience to obtain uniformity of results (Dunn & Van Der Haar, 1990, p.46). Preferably children at the age of 6 to 12 should be palpated since the smaller the child the smaller the thyroid size and the more difficult it is to perform palpation. Puberty may be a problem in older children. Specificity and sensitivity of palpation are low in grades 0 and 1 due to high intra-observer variation (WHO/UNICEF/ICCIDD, 1994; Stanbury & Pinchera, 1994, p.61) and thyroidal palpation has proven to be inaccurate in subjects with small goitre especially in young children (Gaitan & Dunn, 1992; Pardede, 1998). However it gives valuable information on iodine deficiency where ultrasonography is not available (Vitti *et al.*, 1994).

5.2.1.2 Thyroid size by ultrasonography

As the examination for thyroid size can be difficult by palpation, ultrasonography, a means of obtaining an image of the thyroid size by ultrasound wave can provide a more accurate assessment of thyroid size (Dunn & Van Der Haar, 1990, p.37). This technique gives a quantitative measure of thyroid volume that is free of observer bias. The procedure is not invasive and can be used to measure more than 100 subjects a day. Its accuracy diminishes when the gland is quite large, but in such instances precise volume is not important for epidemiological purposes. Its use is strongly recommended to define the goitre endemia in areas of mild iodine deficiency. It can be easily learned within a few days (Gutekunst, 1990; Vitti *et al.*, 1994). The disadvantages of ultrasonography are a requirement for training, expensive equipment and the problem of transport from center to survey site (Stanbury & Pinchera, 1994, p.23). Portable ultrasound equipment is relatively rugged but requires electricity and it can be operated from a car battery with the aid of a transformer (WHO, 1994).

Ultrasonography should be undertaken by well trained, operators who are able to perform up to 100 examinations a day. Since the interpretation of the results is to some extent subjective, before using this method it is

important that operators participate in a calibration exercise with an experienced team (WHO, 1997). Correct interpretation of ultrasonography also relies on the availability of standardized reference criteria from populations whose iodine status is known to be adequate (Pardede *et al.*, 1998).

5.2.2 Cretinism

The frequency, with which cretins occur in a targeted area, has been proposed as a measure of the presence and severity of IDD (Stanbury & Pinchera, 1994, p.51). This might serve admirably if the rate is sufficiently high and statistically reliable numbers can be obtained in reasonable time and if observers are sufficiently skilled in recognizing cretins apart from others with physical findings that superficially resemble those of cretinism. Because cretinism is a clinical diagnosis of a disorder with a presentation spectrum from mild to devastatingly severe, it is difficult to identify all the affected individuals in a population (WHO, 1994). In fact, the more mildly affected cretins may not be diagnosed except by clinical experts or by using specialized methods, for example audiometric or psychometric tests. A significant amount of time may be required to perform the necessary physical examination.

While cretinism results from iodine deficiency during intrauterine life and early childhood, it is most easily diagnosed in later childhood and adulthood (WHO, 1994). In a qualitative sense, therefore, the presence of cretins in a community, even if the prevalence is very low, is significant because it demonstrates that individuals were exposed to a marked environmental iodine deficiency sometime in the past. While this does not necessarily reflect a population's current iodine status, it may have considerable advocacy value. As iodine deficiency decreases, cretins will no longer be born, cretinism will progressively disappear as has occurred in Switzerland and the condition will lose its value for monitoring IDD. However, sub-clinical cretinous manifestations will still have to be taken

into account in assessing the disability-burden in areas of severe iodine deficiency.

5.2.3 Radioiodine uptake

The uptake of radioactive iodine by an individual thyroid is dependent on the amount of stable, that is, non-radioactive iodine in the diet. This is the basis for using radioactive iodine to evaluate thyroid function (WHO, 1994). This test is widely used in industrialized countries to measure avidity of the thyroid for iodine (Dunn & Van Der Haar, 1990, p.43). An elevated radioiodine uptake shows that at the moment of testing, the thyroid lacks iodine (Stanbury & Pinchera, 1994, p.56). This test, however need expensive and cumbersome apparatus, trained observers, and a supply of the radioisotope. It also entails a small radiation exposure to both subject and investigator (Dunn & Van Der Haar, 1990, p.44).

6. IDD CONTROL PROGRAM

The introduction of a planned program is the basic prerequisite for progress and success to national elimination of IDD (Van Der Haar, 1997) and the primary responsibility for developing an approach will always be with the government. Development of a program begins with high level, advocacy to achieve broad commitment to universal salt iodisation as a major national solution to IDD. As the program is progressing, high level advocacy merits continued attention because at all stages, decisions about resources and priorities by the leaders of government and salt enterprises can have implications for its continued effectiveness. The governmental agency responsible for nutrition or public health should have a major role in planning and executing the program and it is important to include other relevant ministries and interested groups at an early stage in planning the program (Dunn & Van der Haar, 1990, p.52; Maberly, 1994).

In Lesotho, the National Micronutrient task force coordinated by F.N.C.O was initiated in 1994 following the 1993 Micronutrient survey, which indicated a high prevalence of goitre. The main objective of this multisectoral task force was to plan and implement the IDD interventions (F.N.C.O, 1994). This task force included representatives from various government ministries working directly or indirectly with nutritional issues, which included ministry of health, agriculture, local government, trade and industry, education, statistics and the National University of Lesotho. Iodised oil capsules were then distributed to all people between the age of 2 to 49 in 1995 to 1996 and in 1997 to 1998. The legislation on universal salt iodisation was drafted as a long-term intervention in 1995. This legislation was made law in March 1999 and was promulgated in March 2000.

Hetzel (1987, p.42) has conceived a model (Figure 4), which identifies the key factors, which are involved in a national IDD program. The success of the "Hetzel wheel" is dependent on full support from political and legislative authority to carry out the program. The major components of a national program to eliminate IDD include: advocacy, education and marketing; Intervention, design and implementation; communication and social marketing and evaluation. Underlying all these components is a sustainable monitoring process (Maberly, 1994). For example in Ecuador, the implementation of the above components enabled the program to improve its interventions and activities (Vanormellingen & Vanderheuden, 1994). The functions of the IDD control unit must be maintained intact with an appropriate budget to ensure permanent success of the IDD control program (Dunn & Van Der Haar, 1990, p.46). IDD control costs money and United Nations (UN) agencies (including UNICEF, UNDP, World Bank, Kiwanis international) in a position to provide substantial financial support should be approached.

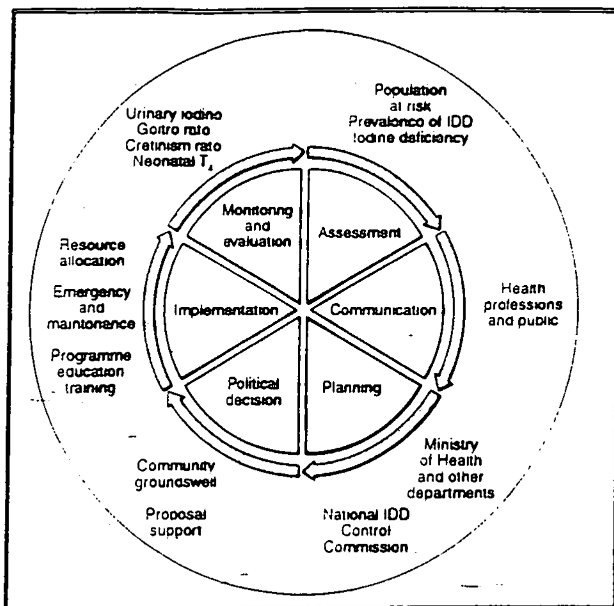

Figure 4. A model showing the social process involved in a National IDD control program (Hetzel, 1987).

6.1 SITUATION ANALYSIS

A situation analysis is the first step in planning a program (Dunn & Van Der Haar, 1990, p.58). The available information should be reviewed concentrating on the extent and severity of iodine deficiency, special factors which influence IDD and its severity, health services available for implementation of IDD control program and the possibilities for prevention of iodine deficiency.

According to Stanbury (1987, p.36), IDD programs in countries or regions can be categorized as non-existent, existent but needing substantial modification, and existent needing only strengthening. The strategy to be adopted will depend on the status. For countries in the first category, the plan should include a survey of the extent and severity of the problem region-wise, analysis of salt production and distribution and identification

of the best point of iodisation. For countries in the second category, the salt production, distribution, and consumption patterns should be reviewed to identify the bottlenecks hampering successful implementation of control programs. For countries in the third category, the ongoing program should be periodically reviewed to ensure that its tempo is maintained. Participation and agreement are the key concepts for a situation analysis since their implication creates commitment towards the activities that must be undertaken to control the IDD problem (Hetzel, 1993a, p.549).

6.2 POLITICAL AWARENESS

A control program directed towards the sustained elimination of IDD need to be broadly based so that interventions become accepted community practices. Hence program tactics need to be synchronous with this objective and dependent upon the empowerment of people to agree with and arrange for an adequate intake of iodine (Marbely, 1994). Iodisation will usually be the major intervention in most programs and its introduction requires legislation and enforcement to make it effective (Dunn & Van der Haar, 1990, p.51). Therefore the government must be convinced that iodised salt is the corrective measure for iodine deficiency.

The resources required for an IDD control program have to be provided by political decision-making (Hetzel, 2000, p.635). To obtain the attention of politicians it is often important to have evidence of support within the community and to obtain this, information of disabilities caused by IDD in terms of loss of productivity and quality of life should be widely published through centres such as schools and clinics and through the media whenever possible (Hetzel, 1993a, p.551). They should also realize that the technology for IDD control is straightforward and easily applied and that an aggressive campaign with appropriate political and financial support has a high probability of success with great political credit for its supporters (Dunn & Van Der Haar, 1990, p.43).

6.3 LEGISLATION AND ENFORCEMENT

The introduction of salt iodisation frequently requires legislation and enforcement to make it effective (Hetzel, 1993a, p.552). First the government must be convinced that iodine deficiency is important and that iodised salt is the corrective measure (which it usually will be). Then a law should be drafted. While specifics of the law may vary in the characteristics of an individual country, the following will usually be an important component: 'All salt for human and animal consumption in the country must be iodised'. The law should clearly designate one governmental unit as responsible for IDD control. While the law should decree salt iodisation it should not leave the technical specifications. It should require periodic reporting by the IDD control unit to appropriate government agencies, should specify enforcement procedures and penalties for non-compliance (Hetzel, 1993a, p.553; Mannar & Dunn, 1995).

A national law on universal salt iodisation can only be introduced meaningfully when all salt producers have been able to build their capacity to comply with the specifications (Van Der Haar, 1997). Small-scale producers require support in obtaining technology and establishing quality assurance before they can comply. Enforcement of the regulation has proved critical to ensuring the quality of iodised salt especially in countries such as Bolivia, where there is multiple small producers (Mannar & Dunn, 1995).

7. PREVENTION AND ELIMINATION OF IDD

The prevention and elimination of IDD relies mainly on fortification with iodine and iodine supplementation. Information education and communication can also play a role in the prevention and elimination of

IDD. This section discusses the methods of interventions that can be implemented to prevent and eliminate IDD.

7.1 IDD INTERVENTION

The IDD intervention programs include both fortification and iodine supplementation.

7.1.1 Fortification

There are several possible vehicles for iodine fortification. Of these possible vehicles, iodised salt is much more cost effective especially with the policy of universal salt iodisation.

7.1.1.1 Salt iodisation

To achieve the goal of IDD elimination by 2000, it was subsequently agreed that all countries would attempt the iodisation of at least 90 percent of salt supplies (Pandav & Anand, 1997, p.47). According to WHO (1994), several foods have been considered as possible vehicles over the past 60 years. They include salt, bread, sweets, milk, sugar and water. Among these, salt has become the most commonly accepted owing to a variety of reasons: Iodisation of salt may be the ideal way to deliver iodine to populations. It is purchased and the cost of sustaining intervention can be passed on to consumers. Iodine in salt can be delivered in physiologic dose with little side effects or toxicity and is very cost effective (Maberly, 1994) additionally, everyone needs salt, its sources are limited and technology is simple (Mannar & Dunn, 1995).

The use of salt as a vehicle for iodine began in 1920's in Switzerland (UNICEF, 1998). This followed the pioneering studies of Dr David Marine in Akron, Ohio, USA in the preceding decade, which showed that administration of iodide tablets over several days twice a year produced a

dramatic decrease of goitre in adolescence. The salt industry then found that it was relatively easy to add iodine at a final stage in the processing of salt before packing. The concept gained ground and soon most salt companies in the USA, Australia and European countries started iodising salt (Mannar & Dunn, 1995). Prophylaxis with iodised salt has been mostly used. There is no doubt about the efficacy of iodised salt but it depends on several factors as indicated in Table 3 (Maberly, 1994).

Table 3. Factors influencing the efficacy of iodised salt (Maberly, 1994).

-Amount of iodine required (100-150μg/day) -Daily salt consumption -Iodine concentration in the salt -Duration of prophylaxis -Handling and distribution of salt -Individual food habits -Goitrogenic factors -Political decisions -Constant surveillance

The concentration of iodine in salt should be adjusted according to the consumption of table salt, which varies greatly. In some countries the consumption has markedly decreased during the last decades (Lamberg, 1993). For example in the USA consumption is about 3g/day, in Switzerland it has decreased from 12 to 6g/day and in Finland it has decreased from 7 to less than 4g/day. The concentration of iodine also varies greatly, for example, in Latin America and Africa, the concentration of 30 to 100mg/kg is used and in Europe between 10 and 50 mg/kg is used.

The duration of prophylaxis is also important and it may take two generations or more before the goitre has disappeared in all age groups (Lindberg *et al.*, 1989). Very important is the handling and distribution of salt. Usually potassium iodide (KI) has been added to the salt but

potassium iodate (KIO_3) is more stable and is presently usually recommended. Both KI and KIO_3 are heavier than the sodium chloride, and therefore they gradually settle to the bottom of the container when iodised salt is stored for a long time. Distribution in smaller packages is therefore advantageous (Lamberg, 1993). Even though KIO_3 is considered stable, studies have confirmed that some iodine is lost when iodised salt is heated or boiled in a solution (Chauhan *et al.*, 1992).

According to Jooste *et al.* (1995) KI is cheaper than the KIO_3 but less stable. KIO_3, rather than KI should be used with impure salt, when salt is exposed to excessive heat and humidity, or when storage and transportation impose long delays before consumption. Alnwick (1988), states that during storage, KIO_3 slowly decomposes to elemental iodine, which evaporates, therefore the concentration of iodine in salt, will decrease over time. The rate of decrease will depend on temperature and humidity during storage, nature of packaging material, extent of exposure to light and duration storage. A study in India showed that small iodine losses of 9 to 10 percent occurred within 15 to 20 days after packaging in polyethene bags where after the iodine content remained constant for 300 days (Chauhan *et al.*, 1992).

The iodine concentration in salt at the point of production should be within the range of 20 to 40mg of iodine per kg of salt (WHO, 1996). This takes into account the following revised assumption; iodine lost is 20 percent from production site to household, another 20 percent is lost during cooking before consumption and the average salt intake per capita is 10g/day. However in many developing countries, salt that has been correctly iodised deteriorates due to excessive long-term exposure to moisture, light, and contaminants. Under these circumstances, iodine losses can be 50 percent or more and this should be taken into account when establishing initial level of iodine in salt. The level of iodisation therefore has to be carefully fixed depending upon the daily consumption

of salt by the population, the nature of the salt to be iodised and the loss of iodine during storage and transportation.

(i) Success in the use of iodised salt:

Success of the iodisation program can be judged by three criteria (Kavishe, 1996, p.264). The first criterion is the achievement of objectives in terms of both process (universal iodisation) and outcome or impact (elimination of IDD). The second criterion of success is the possibility of sustainability in technical and financial terms and especially in awareness. The third criterion of success is the establishment of complementary externalities, such as building up confidence and capacity to tackle other nutrition issues or improving the productivity of communities.

Remarkable success has been achieved by the use of iodised salt to correct iodine deficiency in many industrialized countries since 1920 (Gitau, 1988). For example the introduction of iodised salt yielded great benefits in Switzerland (Stanbury, 1987, p.38) where the burden of cretinism had been a heavy charge on public funds. In 1923 the canton of Berne with a population of little more than 700, 000 had to hospitalise 700 cretins incapable of looking after themselves. Following the introduction of iodised salt, institutions for the deaf and the dumb were closed or used for other purposes. Between 1925 and 1947 the number of exemptions (due to cretinism) for military service dropped from 31 to less than 1 per thousand. The decline in deaf-mutism in several cantons was correlated with introduction and extent of salt iodisation and no cretins were born at the time that iodine prophylaxis was introduced (Pharoah, 1993).

A law requiring obligatory iodisation of all salt with 10mg KI per kg of sodium chloride was proclaimed in 1953 in Croatia and after 10years of implementation a threshold reduction of goitre prevalence was recorded (Kusic & Lechpamer, 1997). In Italy in an area of Easter Tuscany (Tiberina Valley) characterized by moderate iodine deficiency in 1988,

goitre prevalence was lower and urinary iodine excretion was borderline sufficient after implementation of voluntary iodised salt consumption (Aghini-Lombardi *et al.*, 1997). Iodised salt was introduced in all endemic areas in Pakistan in 1977 and prevalence of visible goitre has fallen from 61 to 5 percent (Pharoah, 1993).

A regional strategy for salt iodisation has been advocated in Africa and its implementation is slowly taking place and the success in the use of iodised salt is indicated by reduction in the prevalence of IDD in some of these countries, which include Kenya, Ethiopia, Madagascar, Zambia and Zimbabwe (WHO, 1998). Most countries have formulated IDD control programs and most advanced programs are in Tanzania, Zimbabwe with Ethiopia, Kenya and Malawi having made considerable progress (Kavishe, 1994, p.58). For example in Kenya, there was a decrease in goitre rate after the introduction of universal salt iodisation where in one region, Kericho, the goitre rate decreased from 73 percent in 1969 to 64 percent in 1972 (Gitau, 1988). The goitre prevalence rates for the years 1962, 64,69,72 and 1984 showed a steady decrease with the exception of one region, Kiambu, which had a rate of 16.5 percent in 1962 and 20 percent in 1984. This was probably due to the fact that non-iodised salt was still allowed as long as it was labelled "this does not supply necessary nutrient" (Gitau, 1988). The overall median urinary iodine concentration increased from 0.17 to 1.47µmol/L within one year in the Langkloof area of South Africa after mandatory salt iodisation came into effect (Jooste *et al.*, 2000).

(ii) Salt iodisation legislations:

Several countries have developed legislations with varying iodine forms and concentrations. For example the legislation in Europe allows for voluntary (in fourteen countries) or compulsory (in six countries) iodisation of salt with different iodine forms where the preferred addition is KI at a concentration ranging from 7.5ppm to 50ppm (Burgi, 1992). Germany

uses exclusively KIO_3 at a concentration of 15 to 25ppm and France has opted for sodium iodide (NaI) at a maximal concentration of 15ppm (Burgi, 1992). In the USA KI is used at a concentration of 100ppm.

One of the reasons for the remarkable success of the National Iodine Deficiency Disorders Program (NIDDCP) in India was the legislative measures enacted by the state government/union territories by the issue of notification under the prevention of food Adulteration Act 1954 for the compulsory use of iodised salt instead of non iodised as the common salt for edible purposes (Prakash, 1997, p.11). The legislation considers the loss of iodine in transit and mandated the level of iodine in salt to 30ppm at the manufacturing level and 15ppm at the consumer level. The sale of non-iodised salt has been banned by issuing notifications under Section 7 (clause iv) of the Prevention of Food Adulteration Act by the state governments within territories in India (Pandav & Anand, 1997, p.49). Unfortunately the Indian government has recently revoked this ban.

In Africa KIO_3 is used at concentrations ranging from 25ppm to 100ppm (WHO, 1998) and the sub- Saharan African countries with tropical and sub-tropical climates generally use KIO_3 at levels varying between 50ppm to 100ppm (Jooste *et al.*, 1995). In 1978, the legislation was introduced in Kenya as part of the Food, Drugs and Chemical Substances Act. It stipulated that all table salt or salt for general household use sold in Kenya should contain 33.7mg of KIO_3 per kilogram of salt or if the salt did not contain iodine it should be conspicuously labelled to show that it did not supply a "necessary nutrient" (Alnwick, 1988). Sale of salt with no added KIO_3 was allowed as long as it was clearly indicated on the label but this was revoked in 1988, thus requiring all salt for human consumption to be iodised. An amendment in the legislation requiring iodisation using KIO_3 to 168.5mg/kg was affected in 1989 following a recommendation by a task force for Africa on IDD (Muture & Wainana, 1994).

The legislation on salt iodisation was introduced for the first time in South Africa in December 1954 by the addition of a new regulation 41 to the Food, Drugs and Disinfectants Act 13 of 1929 (Jooste *et al.*, 1995). Reference to KI and iodine-fortified salt in this regulation was subsequently changed (in 1962 and 1966 respectively) to KIO_3 and iodised salt. Regulation 41 on table, iodised and flavoured salt survived the repealed Act 13 of 1929 and was included in the Foodstuffs, Cosmetics and Disinfectants Act 54 of 1972. The regulation prescribes the quality of table salt in terms of moisture content, additives, insoluble matter and chemical composition and the physical characteristics. The current revised Legislation (1995) requires iodisation using KIO_3 at a level between 40 to 60ppm with the exception of low sodium salt, salt packed in bags of 20kg or more and in packages of 1kg or less that are sold at pharmacies.

The legislation in Lesotho was drafted in 1995. The regulation was added to the Legal notice No.13 of 1999, Section 71 of the public health order 1970, in March 1999 and it states that all salt imported or marketed for animal or human consumption must be iodised with KIO_3 and contain between 40 to 60ppm of iodine when entering the country. It further states that every container should be labelled "iodised salt". The exceptions to this regulation include salt intended for use in the manufacture of compound food- stuffs, which is packed in bags of 20kg and labelled "non iodised salt", and salt used for experimental purposes. This Legislation was promulgated in March 2000.

(iii) Techniques in measuring salt iodine levels

Monitoring the salt iodine levels is one of the progress indicators that measure the condition or progress in implementing an IDD control program. There are essentially two techniques for measuring iodine levels in salt; standard titration and rapid test (spot test) method (WHO, 1994):

Standard titration method: This method is conducted in a laboratory. Iodine is liberated using sulphuric acid. The free iodine is titrated with sodium thiosulphate, using starch as an indicator. Slightly different techniques are employed, depending on whether the iodine is in the form of iodate or iodide. Due to its greater stability, KIO_3 is recommended in developing countries rather than KI (PAMM/MI/ICCIDD, 1995).

The titration method is used when great accuracy of iodine level is required. It is used mostly to do operational research to determine the concentration of iodine in salt in the production, distribution and consumer levels. It is a more precise quantitative method than a rapid test method but it is too time-consuming and expensive for purposes of routine national monitoring (WHO/UNICEF/ICCIDD, 1994).

Rapid-test (spot-test): These comprise bottles of starch solution (stabilized), one or more drops of which are placed on the salt. If the salt is alkaline a neutralizing solution is first applied. The intensity of the blue colour, which develops indicates the salt iodine level, up to 50 or 100ppm, depending on the kit used, with an accuracy of +/-10ppm. Most of the rapid (spot) tests available can detect the presence of iodate only (WHO/UNICEF/ICCIDD, 1994).

The rapid test kits are classified into two main categories: Qualitative tests, which indicate only the presence or absence of iodine over a broad range for example a positive test result may simply indicate a salt sample with an iodine content some where between 5-100ppm. Semi-quantitative tests, which give an approximate concentration of the iodine content in salt for example, 0, 25, 50, 75, 100ppm. These tests are not as accurate as the titration method and are not recommended where more precise quantitative measurement of the content of iodine in salt is needed, for

example, for the purpose of law enforcement. They are however technically simple, rapid and can be performed outside the laboratory. They provide more valuable information for the monitoring of salt iodine quality and estimated quantity (PAMM/MI/ICCIDD, 1995). However it must be noted that they should only be used qualitatively.

7.1.1.2 Iodised water

Water, like salt is a dietary necessity, and must be consumed daily. Therefore, water is another physiologically ideal vehicle for introducing iodine. Its big drawback as compared to salt is that sources of drinking water are ubiquitous and therefore, very difficult to control (Dunn, 1994). Nevertheless, under favourable circumstances, water iodisation is a reasonable method for the correction of iodine deficiency.

Iodine added directly to drinking water can correct iodine deficiency. In the simplest form of this approach, a measured amount of iodine, usually as a concentrated solution of KI, or KIO_3, is added directly to drinking water in a jar in an amount appropriate for achieving a daily intake of at least 150µg iodine (Dunn & Van Der Haar, 1990, p.58). The iodine solution is prepared locally and distributed in dropper bottles to schools and to household heads; approximately 8 million people being covered by this approach in northern Thailand.

Another method at the community level is the introduction of porous polymer vessels containing iodine into the water supply, either in hand pumps or into open well water (Fisch *et al.*, 1993). The design of these containers allows the KI solution within the vessel to be slowly released into the well water. This system can run free of trouble for about a year. It is suggested that iodised water may be more convenient than iodised salt and the likelihood of iodine-induced thyrotoxicosis may be less. This method is appropriate at village level if a specific source of drinking water can be identified, otherwise there is a heavy cost as less than 1 percent of

a general water supply is used for drinking purposes (Hetzel, 1993, p.544). It was indicated in Mali that iodisation of well water is very costly and only viable in certain parts of the country where there are adequate water supplies (WHO, 1998).

7.1.1.3 Other alternatives

In principle, virtually any food can be used for fortification with iodine (Dunn, 1994, p.109). Salt and water are especially suitable because they are a dietary necessity that everyone must consume. The problem with using other foodstuffs as vehicles is that their intake is not essential and frequently they are not consumed by those most vulnerable to iodine deficiency. Therefore, it is not often that other foodstuffs deserve serious consideration as primary vehicles for correcting iodine deficiency. Iodine has also been added to tea, bread, sugar and candy. Although it is effective, each of these foodstuffs risk, mal-distribution in the diets of a community, and therefore, wide variations in iodine intake may result.

Dunn (1996) suggests that these alternative approaches should generally be discouraged because they divert attention and resources from iodised salt and most of the proposed vehicles are consumed disproportionately in the population, slighting the groups with the worst iodine deficiency that is, poor rural women and children (Dunn, 1996). For example it was concluded in Germany that allowing the spill over of iodine from dairy herds to effect iodisation offers an alternative (Phillips, 1997). This has the disadvantage of being considerably more haphazard as the amounts of iodine entering the human food chain will depend on both farming practice and the level of consumption of key foodstuffs, in particular liquid milk.

7.1.2 Supplementation

Iodised oil and direct iodine supplements are used for iodine supplementation in a population.

7.1.2.1 Iodised oil

The administration of iodised oil to entire populations, and especially to women of childbearing age and during pregnancy has, been proposed as an emergency prophylactic and therapeutic approach in areas with severe iodine deficiency, complicated by endemic cretinism and where universal salt iodisation has not yet been successfully introduced (Ermans, 1994; Delange, 1996). This leads to eradication of goitre and cretinism in a population (Benmiloud *et al.*, 1994).

Compared to iodised salt, iodised oil has several distinct disadvantages (Dunn, 1994, p.110). First, oral administration requires direct contact with every targeted subject and this takes more effort and expense than mass prophylaxis through the salt distribution channels. Also the oil is given only at infrequent intervals as compared to the constant daily ration, which is received with iodised salt. Therefore, body stores of iodine will be quite high shortly after administration and then taper off to low levels later on. The major advantage of iodised oil administration is that it can be implemented immediately, and does not involve the complexities of altering salt production and trade.

Iodised oil can be given either by intramuscular injection or orally. The duration of effectiveness of injected iodised oil exceeds that of oral iodised oil by far and may thus appear to be a most convenient and effective method for iodised oil administration (Furnee, 1997). However, there are a number of shortcomings attached to injecting iodised oil.

Although the chances for local inflammatory reaction at the injection site are trivial, it is a painful experience to receive the iodised oil intramuscularly. In order to minimize the complications associated with injecting the medical team should be thoroughly trained in aseptic techniques and skills. To diminish the chances of spreading highly infectious diseases either disposable syringes and needles are needed or equipment should be available to ensure proper sterilization of the instrument (Furnee, 1997).

Oral iodised oil, either as capsules or by using a dispenser, can be administered by any responsible person such as a primary health care worker or a school teacher. Oral iodised oil has been winning ground since 1974 for those who do not have access to iodised salt (Pharoah, 1993; Furnee, 1997). Iodised oil can provide effective control for up to a year but requires individual contact with each target subject and provides uneven levels of iodine during the months following administration (Dunn, 1996).

Several recent studies have examined the optimal dose and duration of effect for oral iodised oil. In one investigation in young adults, small doses containing 120mg of iodine seemed satisfactory for coverage for a period of six months to a year. A collaborative study of school children in Algeria, India, and Peru showed that a dose of 480mg of iodine is barely adequate for a year's coverage, and half that dose gave satisfactory coverage for six months (Dunn, 1994, p.111). Some studies suggest that smaller doses than 480mg may be equally effective at least for a year (Dunn & Van Der Haar, 1990, p.59). Based on the available scientific and programmatic evidence, the proposed iodised oil prevention schedule, (which include dosage of 400-960mg for 1 year to non pregnant women), will lead to no detectable adverse effects on human health. The potential benefits to be derived greatly outweigh the potential risks in areas of moderate and severe IDD prevalence where iodised salt is not available and is unlikely to be made available in the short term (WHO, 1996).

7.1.2.2 Direct iodine supplements

In circumstances where iodised salt or other alternatives are not readily available, iodine supplements in the form of tablets or drops can successfully correct iodine deficiency. Oral potassium iodide solution was found to be effective for the prophylaxis of iodine deficiency if given as a dose of 30mg monthly or 8mg biweekly (Dunn & Todd, 1998). In Sucre, Bolivia, local health authorities have mixed concentrated solutions of potassium iodide and distributed them to schools and households with instruction on proper daily administration (Dunn, 1994, p.112). Such daily dosing with iodine is highly effective and relatively inexpensive. Its major draw back is that it requires the constant attention of responsible individuals to see that the iodine is actually ingested and that they must be given individually and repetitively (Dunn & Todd, 1998). This oversight is difficult to maintain in most public health programs in developing countries (Dunn, 1994, p.112).

Subjects can receive oral iodine directly in the form of Lugol's solution. Lugol's solution is commonly found even in small rural hospitals in developing countries (Dunn & Van Der Haar, 1990, p.59). It is widely available as an antiseptic and contains free iodine 50g/l (Dunn & Todd, 1998). In contrast to iodised oil, Lugol's iodine is stored in the body only by thyroid recycling. Accordingly, its duration of effect will be considered shorter than that of iodised oil, and repeated applications are required. Precise guidelines for the optimal dose and duration of effect are not available and studies to supply this information are being developed. The great advantages of Lugol's iodine are its wide availability and low cost. It also provides a supply of iodine that is closer to physiologic needs. However, effective use of Lugol's iodine requires responsible people to distribute it and to see that the correct dose is given at the proper intervals

(Dunn & Van Der Haar, 1990, p.59) because large doses can be toxic to the gastro-intestine (Dunn & Todd, 1998).

7.2 INFORMATION, EDUCATION AND COMMUNICATION

Information, education and communication (IEC) are the most important (and most neglected) components of an IDD control program (Dunn & Van der Haar, 1990, p.63). Many programs in the past have introduced iodine supplementation measures without educating the target group or other involved parties to the importance of IDD and its correction. Such unexplained interventions may meet with indifference or resistance and frequently are not sustained. An aggressive campaign to make all interested parties aware of IDD and its correction should be a cornerstone of an IDD control program. Education should be at all levels including the following; politicians and decision makers, health workers, workers in the salt trade, citizen groups, and the iodine deficient community. All affected parties must understand the importance of iodine deficiency, its consequences and the means for its correction. Education begins with health authorities in the country and extends to other branches of the government, the health providers, industry, marketing and the affected communities (Dunn, 1996).

One of the most crucial challenges in the process of eliminating IDD is raising awareness of how widespread and damaging iodine deficiency is. Although 1.6 billion are at risk of IDD, most people know nothing about it and even many health care workers remain unaware of the full impact IDD has, particularly on mental development (PMM/MI/ICCIDD, 1995). For example in India the Non Governmental Organisations (NGOs) reported poor awareness of the causes, consequences and preventative measures associated with IDD, even among district officials (Pandav *et al.*, 1995). The public needs to know that once salt is iodised, a crucial collective step has been taken that changes the course of a nation's development future (PAMM/MI/ICCIDD, 1995).

Prakash (1997) state that the population belonging to the lower socio-economic strata of society are unaware of IDD and the preventive properties of iodised salt and so prefer or are tempted to purchase plain salt because of its low cost. Consequently, an appropriate IEC program with simple messages in terms of do's and dont's using mass media, folklore, Television, radio, posters, and other media of communication should be undertaken. For example in Bolivia, health personnel, at all levels received continuous training about the importance of consuming iodised salt. Radio messages were passed throughout the country in local languages using the radio (Freire *et al.*, 1996).

In Lesotho, after the 1993 National Micronutrient survey, messages were passed through local radio stations, pamphlets and local gatherings (Pitsos) on the consequences of iodine deficiency and the importance of iodised salt. This resulted in an increase in the use of iodised salt by household as indicated by Sebotsa (1998) where 15 percent of households used non-iodised salt compared to 40 percent indicated by Ministry of Health in 1988. The micronutrient task force however concentrated less on political awareness hence the legislation drafted in 1994 was only made law in 1999 and promulgated in 2000.

Communication does not only put people in touch with each other, but it also builds partnerships of trust, which share equally the essential information in ways which are mutually beneficial. Communication efforts are the bridge between people's knowledge, on awareness of needs, and the benefit of the proposed change (Haxton, 1994, p.135). Ideas for raising awareness of IDD according to UNICEF (1995) include prizes to students of all ages for best poster, essays or science projects about overcoming iodine deficiency and holding IDD day each year.

8. MONITORING AND EVALUATION

Every program needs constant monitoring and evaluation in order to be effective.

8.1 MONITORING

Rubin (1995, p.6) explains monitoring as a continuous, methodical process of data collection and information gathering throughout the life of a project. The information collected can be used for regular evaluation of progress so that adjustments can be made while work is going on. Monitoring is also used to mean the systematic tracking of particular conditions, or set of conditions to identify trends. Information for tracking progress against previously agreed plans and milestones is routinely gathered. The changes that result from project activities can be identified that is both the effects and the impact. If there are discrepancies between actual and planned progress, corrective action can be taken. This can include changing the overall purpose and plan the activity. Monitoring can also mean keeping a check on the use of resources. Questions for later evaluation can be identified during monitoring.

Once implemented, an iodisation program needs constant monitoring with prompt corrections of branches as they develop (WHO/UNICEF/ICCIDD, 1994). Surveys of representative groups with appropriate indicators and quality control of iodised salt production and consumption are the usual monitoring tools. A system incorporating these or other appropriate measures should be put in place at the beginning of an iodisation program and should include regular follow up, public reporting of its results and sufficient institutional resources to make it realistic (Dunn, 1996).

The success of any of the IDD control programs depends on ensuring the specified iodine content at the consumer level (PAMM/MI/UNICEF, 1995). Towards this end the iodine content should be monitored at the iodisation plant, intermediate points, retail outlets and households. Loss of iodine from salt at any point in the distribution may limit success of the program. Even after the IDD control has been achieved, it must be constantly monitored or IDD will reappear (Mannar, 1987, p.114).

In the National Capital Territory of Delhi, a study was conducted to assess the iodine content of salt consumed and the iodine status amongst school children in urban, rural and urban slum areas (Kapril *et al.*, 1996). This study revealed that nearly 34 percent of the families in the three areas consumed salt with less than 15ppm of iodine. A similar study was conducted in Guatemala where it was found that 60 percent of salt samples were below the mandated range (Stewart *et al.*, 1996). In Bolivia analysis showed that 5.3 percent of the rural households were using block and granular salt, and only 10 percent of the samples of salt of this type was iodised (Freire *et al.*, 1996).

In South Africa, to assess the situation in the country, a sample run to determine the presence and amounts of iodine in table salt on the shelves of retail outlets was incorporated into the routine monitoring program for the period 6 May 1996 to March 1997. Of the 521 samples analysed, 42.4 percent were below 40 and 60ppm. No iodine was detected in 12.3 percent of the samples (Department of Health, South Africa, 1997). A recent study in Lesotho indicated that 36 percent of salt samples at retail level were within the legal specification of 40 to 60ppm (Sebotsa, 1998). Twenty percent of the household salt samples were below 20ppm, which according to WHO (1994) is the most common cut-off point for defining adequately iodised salt, while 15.3 percent of the household salt samples were non-iodised salt.

According to Pandav and Anand (1997, p.53) success of the National IDD control program depends primarily on the iodine level at the production level, the retailer level, and finally the consumer level. For an effective salt iodisation program, monitoring the levels of iodine at various stages and under various circumstances is one of the most important factors. They also suggested that though the government has a system for monitoring, it is necessary to supplement this by external agencies. NGO's have an important role to play in this and its success has been proven by recent studies undertaken in India. Three NGO's already involved in health and development activities, collected salt samples monthly from households and shops in selected villages over a six months period for iodine content analysis (Pandav *et al.*, 1995). The operational program must include clear safe guards for continued monitoring on a permanent basis (Dunn & Van Der Haar, 1990, p.58).

Monitoring and evaluation are essential for iodisation programs particularly because there is a need to ensure that the iodine deficiency is quantitatively corrected in order to reduce foetal damage and impaired mental function in children (Hetzel, 2000, p.635). The recommended criteria for use as a core indicator in monitoring progress towards the goal of eliminating IDD as a significant public health problem is presented in Table 4. These criteria provide the major indicators for progress towards the goal of elimination of IDD (Hetzel, 2000, p.636). They require adequate laboratory services so that the monitoring and independent evaluation can be carried out which are essential to ensure sustainability.

Table 5 includes both IDD status indicators (urinary iodine, thyroid size and neonatal TSH) and a control program process indicator (salt iodisation), since it is important to ensure sustained control of iodine deficiency for an entire population rather than focus on reaching goals based on measuring the IDD status of a single group (WHO/UNICEF/ICCIDD, 1994).

Table 4. Criteria for monitoring progress towards eliminating IDD as a public health problem (WHO/UNICEF/ICCIDD, 1994).

INIDICATOR	GOAL
Salt iodisation	
Proportion of households consuming effectively iodised salt	>90%
Urinary iodine	
Proportion below 100μg/l	<50%
Proportion below 50μg/l	<20%
Thyroid size	
In school children 6-12 years of age Proportion with enlarged thyroid, by palpation or ultrasound	<5%
Neonatal TSH	
Proportion with levels 5mU/l whole blood	<3%

8.2 EVALUATION

Rubin (1995, p.7) explains evaluation as a learning and management tool. It is an assessment of what has taken place in order to improve future work. Measuring analysis and interpreting change help people to determine how far objectives have been achieved and whether the initial assumptions about what would happen were right and to make judgments about the effectiveness, efficiency, impact and sustainability of work. Evaluation uses information gathered during regular monitoring but may need other information as well. It often uses baseline information collected at the very beginning, against which progress can be measured. It happens to set times in the life of a project. It looks at the relevance,

effectiveness and impact of a project in the aim of improving an existing project or influencing future policies programs and projects.

Dunn and Van Der Haar (1990, p.59) state that once the IDD control program is in operation, periodic evaluation of its biological effects is mandatory. A reasonable period for a repeat survey is three years after the introduction of the iodisation program. It is highly desirable to re-examine subjects in the same schools or villages used for the initial assessment. A network of "sentinel communities", carefully selected to be representative of the iodine-deficient population, can be very valuable for periodic reassessment by goitre survey and urinary iodine measurement. The evaluation measures used are surveys for clinical manifestation of IDD with emphasis on the program and incidence of neonatal hypothyroidism in the areas receiving iodised salt (Stanbury, 1987, p.39).

9. SUMMARY

Iodine is an essential nutrient for the synthesis of thyroid hormones, which are essential for both physical and mental development in man and animals. A deficiency of iodine is both easy and inexpensive to prevent but it continues to be a significant health problem in many countries.

The clinical and sub-clinical manifestations of iodine deficiency are collectively included in the term IDD. Iodine deficiency not only causes goitre (the most obvious sign of iodine deficiency), it may also result in irreversible brain damage in the foetus and retarded psychomotor development in the child. The more severe consequences of iodine deficiency include cretinism, mental retardation and deaf mutism. While most goitres, are attributable to lack of iodine in the diet, other factors also contribute of iodine deficiency and lead to distinct epidemiological patterns of IDD in different population. These factors include; age, sex, goitrogens, socioeconomic and geographical situation.

School children are a convenient test group for severity of IDD in a community because they are easily accessible, reflect the current status of iodine nutrition and are a major priority group for prompt correction of iodine deficiency. Urinary iodine analysis is the most common biochemical method for assessing the iodine status of the population because it directly reflects dietary iodine intake. Goitre is usually the most obvious sign of iodine deficiency therefore it is important to document the goitre prevalence in a population to determine whether more serious consequences of iodine deficiency are likely to be present.

Once the presence of iodine deficiency is established, a program to deal with it must be developed. Several ministries and NGO's must be represented in the design and implementation of the program. Their appropriateness and importance for representation will vary among countries. A situation analysis is the first step in planning a program and it should consider the location and severity of the iodine deficiency and the factors affecting the choice of intervention measures.

Iodisation of all edible salt is a long- term sustainable preventative solution to eliminate iodine deficiency disorders and remarkable success has been achieved by the use of iodised salt to correct iodine deficiency in many countries. The administration of iodised oil, particularly oral iodised oil, has, been proposed as an emergency prophylactic and therapeutic approach in areas with severe iodine deficiency where universal salt iodisation has not yet been successfully introduced. Education and communication are the integral components of an IDD control program. A successful program must provide adequate surveillance of the biological impact of iodisation by periodic surveys of goitre and urinary iodine and by constant monitoring of the iodine level of iodised salt. Monitoring and evaluation of the effects of implementation are crucial to the long-range success of an IDD control program.

CHAPTER 3

METHODOLOGY

1. INTRODUCTION

In this chapter, the study design, selection of subjects, experimental procedures for the collection of information, clinical examination (palpation), salt testing, biochemical (urine analysis) and statistical analysis will be discussed. Efforts were made to have a sample that would represent the country. The study was designed to include all the districts of Lesotho and the sample size was based on the WHO/UNICEF/ICCIDD, (1994) recommendations. Assurance was made to obtain both reliable and valid results and a number of measures were undertaken to ensure validity and reliability as defined below:

Validity is the degree to which a test measures what it is supposed to measure and consequently permits appropriate interpretation of results (Gay, 1996, p.35).

Reliability is the degree to which a test consistently measures whatever it measures (Gay, 1996, p.40). The more reliable a test is the more confidence it gives that the results obtained from the administration of the test are essentially the same results that would be obtained if the test were re-administered.

2. STUDY DESIGN

This study, conducted in 1999, was designed as a cross sectional study to estimate the current IDD status and measure the use and effectiveness of IDD interventions. The outcome indicators (from both biochemical and clinical indicators) and process indicators (salt iodisation) were measured

among the primary school children in Lesotho. Schools were stratified into ecological zones and children were randomly selected to measure the relevant variables. The schematic outline of the design in this study is given in Figure 5.

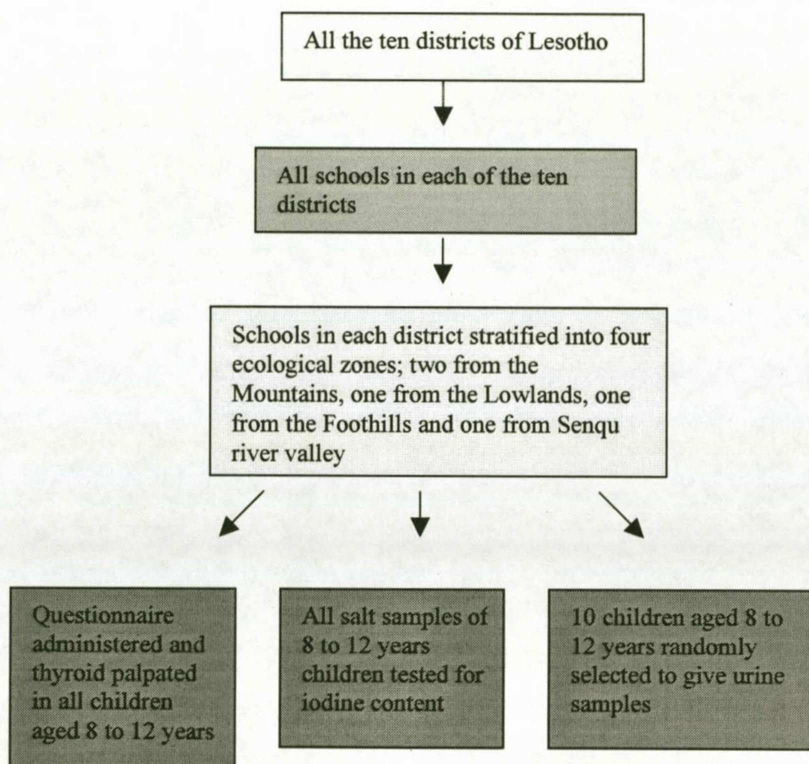

Figure 5. A schematic outline of the study design

3. RANDOMISATION AND REPRESENTATIVENESS

Lesotho is a country with an area of 30,335sq km (Wolde-Gebriel, 1993). About 75 percent of the country is mountainous. Ecologically the country is divided into four distinct ecological zones mainly on the basis of altitude, namely, Mountains (Highlands), Foothills, Senqu river valley and Lowlands. The country is divided into ten administrative districts (Appendix 2) all of them having some parts of the various ecological zones. All the areas in the country have an altitude of more than 1500 metres above sea level. Climate varies with differing topography whereby

the Mountains have cool summers and cold winters often accompanied by snow, while the lowlands have warmer summers with occasional rain and very dry but cold winters.

In order to have a representative sample, selection was done with the aid of Lesotho Bureau of Statistics. The ten administrative districts and all the ecological zones were included in the sample. The sampling frame therefore consisted of lists of primary schools categorized by ecological zones in each district. Stratified random sampling was then used to select 5 schools in each district (two schools from the Mountains, one from the Lowlands, one from the Foothills and one from Senqu river valley). Two schools were selected from the Mountains in order to have a larger sample size in this zone than in the other zones. This is because about 75 percent of the country is Mountainous. Fifty primary schools in the whole country were therefore included in the sample (Appendix 6).

4. STUDY POPULATION

4.1 TARGET POPULATION

Based on the recommendation of WHO/UNICEF/ICCIDD (1994), school children aged 8 to 12 years were selected as the study population. This age group was chosen based on the fact that in younger children, the thyroid is more difficult to examine and in older children, stage of puberty might be an additional variable. Table 5 indicates the total number of primary school children in each district and ecological zones of Lesotho.

Table 5. The total number of primary children in Lesotho by districts and ecological zones (Source: Ministry of Education)

District	Mountains	Lowlands	Foothills	Senqu river valley	**Total**
Thabatseka	16292	6931	2531	1409	**27 163**
Leribe	9676	15986	9424	3492	**38 578**
Maseru	4031	21912	11518	19519	**56 980**
Mokhotlong	9093	3261	1142	1107	**14 603**
Buthabuthe	4957	7026	3342	2210	**17 535**
Mohaleshoek	4163	9314	4534	3264	**21 275**
Berea	2702	15302	2986	2247	**23 237**
Quthing	7259	6971	4243	1995	**20 468**
Qacha's Nek	9891	3075	1100	1316	**15 382**
Mafeteng	4499	9813	4601	3223	**22 136**
TOTAL	**72563**	**99591**	**45421**	**39782**	**257 357**

4.2 SAMPLE SIZE

The sample size chosen was adequate to get representative results because it was based on recommendations from previous international studies as described hereafter.

4.2.1 Urinary iodine determination

4.2.1.1 The recommended sample size

Forty or more subjects are needed to determine the median concentration of urinary iodine in a region (Dunn & Van Der Haar, 1990, p.38; Dunn *et al.*, 1993, p.9; Stunbury, 1994, p.56). WHO/UNICEF/ICCIDD (1994) also indicates that the recommended sample size in a population for collection of biological specimens like urine is 300 (30 clusters x 10 children per cluster).

4.2.1.2 Study sample size

In this study 50 children were selected to give urine samples in each district. To give valid estimates at the national level, ten children in each school (50 schools x 10 children per school) were selected resulting in 500 children selected to give urine samples.

4.2.2 Thyroid size determination

4.2.2.1 The recommended sample size

The recommended sample size for school based goitre survey is 1200 children (30 clusters x 40 children per cluster) (WHO/UNICEF/ICCIDD, 1994).

4.2.2.2 Study sample size

All children aged 8 to 12 years in a school were selected and assessed for thyroid size in this study. The sample size therefore differed according to the number of children aged 8 to 12 years in each of the 50 schools, which ranged from 55 to 131 children palpated in each school (50 schools x 55-131 children). This resulted in 4071 children included for thyroid size determination.

4.2.3 Salt iodisation level determination

4.2.3.1 Recommended sample size

For schools with an enrolment of 100-1000 pupils, WHO/UNICEF/ICCIDD (1994) recommend that at least 35 salt samples should be tested for the level of iodine.

4.2.3.2 Study sample size

In this study, salt samples from all children aged 8 to 12 years were tested for the level of iodine resulting in the range of 55 to 131 salt samples tested in different schools. This resulted in 4071 salt samples tested for the whole country.

5. EXCLUSION CRITERIA

Four children were excluded from the selected sample in this study. The children were excluded based on the following exclusion criteria:

5.1 CHILDREN WITH SEVERE PEM

Many studies indicate that severe PEM affects thyroid function and the metabolism of thyroid hormones. It may also interfere with iodide uptake by the thyroid and with thyroglobulin formation (Hetzel, 1993, p.542). Thyroid size in PEM is therefore not only influenced by dietary intake of iodine. The inclusion of children with PEM would give misleading results and conclusions on thyroid size determination in this study.

Weights of suspected children were taken using the calibrated digital bathroom scale. Using the National Centre for Health Statistics (NCHS, 1976) growth charts (Appendix 7), weights were plotted against ages and the expected weight for age determined. The nurses assessed the children on presence and absence of oedema. The "Wellcome classification" (Table 6) was used to determine the severity of PEM (WHO, 1991).

Table 6. Wellcome classification of PEM (WHO, 1991)

% expected weight for age	**Oedema present**	**Oedema absent**
60-80%	Kwashiorkor	Underweight
<60%	Marasmic-Kwashiorkor	Marasmus

The following cut-off point was used:

Severe malnutrition: A child with Kwashiorkor, Marasmus or Marasmic-kwashiorkor.

5.2 CHILDREN WITH SEVERE DIARRHOEA AND FEVER

Variations in urinary volume (through dehydration, increased fluid consumption or dilution) have been shown to provide misleading estimate of the actual urinary iodine level (Dunn & Van Der Haar, 1990, p.55; Dunn *et al.*, 1993, p.33). There is therefore a possibility that children with severe diarrhoea and fever would have variations in urinary volume, which would affect the results on urinary iodine concentration determination in this study.

Children were questioned and assessed by the nurses on symptoms of severe diarrhoea and fever. Based on definitions from Werner (1988, p.45) and WHO (1992), the following cut-off points were used in this study:

Severe diarrhoea: Loose or watery stools more than 3 times a day; 48 hours before the study.

Fever: Abnormal high temperature with sweating; 48 hours before the study.

6. FIELD WORKERS

6.1 SELECTION

Field workers included three nutritionists (including the researcher) and two nurses from the F.N.C.O and the Ministry of Health respectively. The two nutritionists and the two nurses palpated the children for thyroid size and tested salt for iodine content. The two nurses also assessed the suspected children (for exclusion) for clinical signs of PEM, severe diarrhoea and fever. There were also three officers who have degrees in sociology and working as regional officers at F.N.C.O who interviewed and recorded the goitre grade of the children in this study. The role of the researcher (nutritionist) was to organise for the study, train the field workers, supervise during field visits and verified the work every day after each field visit. Excluding the researcher, a team of seven field workers was involved during the study.

6.2 TRAINING

6.2.1 Procedures and measurements

Intensive training was done for three days. All seven, field workers were trained by the researcher. The field workers were first given a clear explanation of the purpose and procedures of the study. They were trained on palpation using standardised procedure for palpation (Appendix 8), the use of test kits and interviewing techniques.

6.2.2 Pilot study

A pilot study was done in three primary schools in Maseru district and the aims were to:

- Expose the field workers to problems that may be encountered in the field and how to solve them. That is, to gain practical experience and to test all the measurements and field work, procedures under field conditions.
- Standardise methods and eliminate errors during palpation and salt testing.
- To ensure good recording and probing for answers.
- Evaluate field workers.

A total of 275 children were included in the pilot study. No problems were encountered with palpation and salt testing. It was, however, found that some children did not know their ages and whether they received the iodised oil capsules or not. Therefore, it was recommended from this pilot study that class teachers be present during interview to double check the ages from the enrolment list and supplementation of iodised oil capsules information from school record books. It was also recommended that two observers perform palpation separately on the same child to achieve a greater degree of agreement in determination of the thyroid size.

7. ETHICAL CONSIDERATIONS

The Ethics Committee of the Faculty of Health Sciences of the University of Orange Free State gave its approval to conducting this study (Ethics document number ETOVS NR 162/99). An informed consent form written in Sesotho or English (Appendix 9) had to be signed first by the parents or guardians and then by each child who participated in the study. Those who were not able to write signed with a cross. Permission for the study

was also granted by the Ministry of Education for the whole country and also by chiefs and headmasters of the selected schools.

8. MEASUREMENTS AND CALCULATIONS

The variables measured in this study were urinary iodine concentration, thyroid size, iodine content of table salt and iodised oil supplementation. The prevalence of goitre and coverage on the use of iodised salt and iodised oil supplementation were calculated.

8.1 MEASUREMENTS

8.1.1 Urinary iodine concentration (as a biochemical indicator)

8.1.1.1 Theoretical procedure for urine analysis

Casual urine samples or 24-hour urine samples can be collected for urinary iodine analysis. There are many different urinary iodine methods available, which range from technically sophisticated/automated techniques to simple manual techniques with limited instrumentation requirements (Dunn *et al.*, 1993, p.73; May & May, 1998). The Sandell-Kolthoff reaction with some prior step involving ashing or digestion is usually the most practical approach. The results can be expressed per gram creatinine or per litre of urine.

8.1.1.2 Reliability and validity in urinary iodine analysis

The urinary iodine methods are reliable and valid when quality control procedures are implemented. Concentrations may vary considerably among individuals and even within the same individual at different times. Studies have shown that such variation is damped by the inclusion of enough representative samples from the test community (Dunn, 1996; WHO/UNICEF/ICCIDD, 1994). According to May and May (1998) the

following measures can be followed during quality control and to ensure reliability and validity in urinary iodine analysis.

Specimen collection and storage

- Specimens should be collected into tightly closed screw-capped plastic containers and kept cold or frozen until they reach the laboratory.
- Approximately 5ml is adequate to send to the laboratory for analysis and once in the laboratory the specimens should be sorted and frozen in batches that are convenient for future thawing when analysis is performed.
- Quality control within the laboratory
- It is essential that the laboratory is quality assured at every level, which is often termed Total Laboratory Quality Assurance (TLQA). This is a broad concept and involves consistent monitoring of instrumentation, environment and method performance, as well as development and implementation of specific laboratory management strategies.
- When establishing a new method and regularly thereafter, key equipment such as balance, digestion units/heating blocks, spectrophotometer and pipettes should be calibrated and / or checked for adequate performance.
- When the urinary iodine method is set up in the laboratory, the performance characteristics of the method must be studied and no routine specimen analysis should be started until acceptance is established.
- Quality control (QC) samples must be obtained and assayed in a consistent quality control program. This involves preparing or obtaining urine specimens with various iodine concentrations and running them in every assay, along with the standards and unknown specimens.

- Participation in an external quality control exchange program is an important, independent means of assessing laboratory performance.

8.1.1.3 Study procedure for sample collection and urinary iodine analysis

Casual urine samples were collected from ten children in each school based on the WHO/UNICEF/ICCIDD (1994) recommendations. Measurement of urinary iodine excretion was done at the National University of Lesotho (NUL) using the alkaline ashing with spectrophotometric reading of the Sandell-Kolthoff reaction. The procedures followed were from the "Improved Routine Method for determination of total iodine in urine and milk" by Aumont and Tresol (1986) (Appendix 10). They include alkaline ashing, iodide extraction from ash residue and determination of the Sandell-Kolthoff reaction. This method has a precision below 10 percent and sensitivity below 2 parts per billion in NUL laboratory. The results were expressed as micrograms per litre (µg/l).

To ensure quality control and to obtain valid and reliable results, the following procedures were followed in determining urinary iodine concentration:

- 50 and 500 samples were collected at district level and national level respectively and these are above the recommended representative samples (40 and 300 respectively).
- Samples were collected in tightly closed screw-capped plastic containers to prevent leakage and evaporation and kept cold until they reached the laboratory where they were refrigerated while awaiting analysis to avoid mould growth.

- 20ml capacity bottles were used therefore approximately 20ml urine samples were collected from each child to give enough samples in case analysis had to be repeated.
- In the laboratory, samples were sorted on arrival and kept in batches of schools and districts to avoid confusion and inconvenience during analysis.
- The equipment used in the laboratory were calibrated and checked for adequate performance before analysis.
- The performance characteristics of the method used are checked every 3 months to enable the analyst to maintain confidence in the method performance and this was checked again a week before analysis could take place.
- The person who analysed the samples was well trained at Medical Research Council in Cape Town and has analysed urine samples from other ministries and organisations in Lesotho.

8.1.1.4 The cut-off points

The following recently revised WHO/UNICE/ICCIDD (1999) epidemiological criteria for assessing severity of IDD based on median urinary iodine levels was used:

Median value (µg/l)	Severity of IDD
<20	Severe IDD
20-49	Moderate IDD
50-99	Mild IDD
100-199	Adequate iodine nutrition
200-300	More than adequate iodine intake, may pose an increased risk of IIH
>300	Excessive iodine intake

8.1.2 Thyroid size (as a clinical indicator)

Thyroid size is determined by either inspection and palpation or ultrasonography, which is a more precise and objective method but it is expensive.

8.1.2.1 Theoretical procedure for palpation

Palpation can be done with the examiner standing or sitting in front of the subject or behind the subject. The subject can either be in a standing position or sitting position. The neck of the subject can be either in a normal or extended position. Either the middle thumb or fore and middle finger can be used for palpation. The simplest and most widely accepted criterion is that goitre is present when each lobe of the gland is easily outlined by the fingers of the examiner and is as large or larger than the distal phalanx of the subject's thumb (Demaeyer *et al.*, 1971, p.47; Stanbury, 1987, p.45).

8.1.2.2 Reliability and validity of palpation:

Carefully controlled and blinded studies have shown a large inter-observer variation, especially but not exclusively, in the assessment of smaller enlargements of the thyroid (grade 0 and grade 1)(Stanbury & Pinchera, 1994, p.42). As demonstrated by studies of experienced examiners, misclassification can be as high as 40 percent (WHO/UNICEF/ICCIDD, 1994). It was further indicated that palpation has proven to be inaccurate in smaller children since the smaller the child the smaller the thyroid size and the more difficult it is to perform palpation accurately. However in the absence of ultrasonography, which provides a more precise method for determination of thyroid size, clinical classification of thyroid size into goitre grades using palpation provides an acceptable and simple alternative (WHO, 1993).

According to Dunn and Van Der Haar (1990, p.51) and WHO/UNICE/ICCIDD (1994), reliability and validity of palpation can be assured by:

- The use of standardised technique
- Intensive training of observers
- Supervision of observers by other examiners with experience to obtain uniformity results
- Preferably children age 6 to 12 years should be palpated

8.1.2.3 Study procedures for thyroid size determination

The size of the thyroid was determined by inspection and palpation of children aged 8 to 12 years in each school using the standardised reference for palpation (Appendix 8). In order to ensure standardised determination of thyroid size, the following procedures were followed:

- Experienced field workers (the two nutritionists and two nurses) were recruited for thyroid size determination. They have been involved in previous surveys, which involved palpation. They were trained on palpation during these studies by the Director of F.N.C.O (Masters in Community Nutrition) and by the researcher who is the nutritionist (B.Sc. Med. Hons. Nutrition and Dietetics) at the same office. Both trainers were themselves trained by experienced examiners (Dr. Zwide-Wolde Gebriel, the Director Ethiopian Nutrition Institute and short-term consultant to UNICEF in Lesotho in 1993 and retrained by Dr Kavishe the UNICEF consultant (Lesotho) in 1994 on the same palpation procedure). They have also been involved in training and performing palpations at various occasions.
- Standardised palpation procedure was used and the observers were intensively retrained on this procedure by the researcher. The intensive training of field workers and pilot study were done for five days.

- Children aged 8 to 12 years were selected in each school to reduce both intra and inter-observer variation and the same age group was selected in all the schools visited.
- Palpation was done separately by two trained field workers (one nutritionist and one nurse) and where the two did not agree the lowest grade was recorded. That is, these two trained field workers palpated one child independently and the child was given a piece of paper with the goitre grade on it by each of them. These papers were then taken by the child and given to the recorder (one of the three officers from F.N.C.O).
- Supervision during fieldwork was done by the researcher to ensure that the observers were following the procedures.
- Not more than four field workers were trained for palpation to eliminate a wide variation between different observers and each performed not more than 100 palpations per day to avoid stress, which would lead to errors in palpating.

8.1.2.4 The cut-off points

The following WHO/UNICEF/ICCIDD (1994) criteria for classifying the size of the thyroid were used in this study:

Grade 0	No palpable or visible goitre
Grade 1	A mass in the neck that is consistent with an enlarged thyroid that is palpable but not visible when the neck is in the normal position. It moves upward in the neck as the subject swallows. Nodular alteration(s) can occur even when the thyroid is not visibly enlarged
Grade 2	A swelling in the neck that is visible when the neck is in a normal position and is consistent with an enlarged thyroid when the neck is palpated.

8.1.3 Salt iodisation (as a process indicator)

8.1.3.1 Theoretical procedure for salt iodisation level determination

There are essentially two techniques for measuring iodine levels in salt; the standard titration method and the rapid/spot test method. Standardised procedure for testing salt using rapid test is clearly indicated on the cover of each test kit. A few teaspoonfuls of salt to be checked are taken and spread flat. A drop of the test solution is discharged on the surface of the salt. The colour chart is used to compare and determine the iodine range in the salt. In the absence of any colour indication, a drop of recheck solution on the same spot is discharged and the colour chart is used to compare the iodine range.

8.1.3.2 Reliability and validity of rapid test

Literature shows that rapid tests have an accuracy of +/- 10ppm (WHO/UNICEF/ICCIDD, 1994). However, WHO/UNICEF/ICCIDD (1999) recommends that the rapid test kits should only be used qualitatively, that is, to establish whether or not iodine is present in the salt, and not to estimate the amount of iodine in salt. To ensure reliability and validity of the rapid tests May and May (1998) recommends the following procedures:

- Training for intended users is advisable
- Users must be careful to keep kit components closed to avoid contamination
- Users must be aware of the shelf life of the kits used, which should be stated on the kit. Once the reagent bottles are open, they have a shelf life of approximately 6 months.
- It is important to ensure the quality of the testing performed by use of a "control" salt sample.

- Routine cross checking of sample results from salt testing kits with quantitative laboratory techniques, should be done to give confidence that the kits are performing adequately.

8.1.3.3 Study procedure for determination of salt iodisation level

The salt samples brought from home of children aged 8 to 12 years were tested. The salt iodine level was determined by using the spot tests obtained from UNICEF. They are the semi-quantitative tests, which use a colour chart by which the iodine levels in the salt samples are estimated at the concentrations 0, 25, 50, 75 and 100ppm. The procedures on the cover of the test kits were followed as stated above.

The following procedures were followed for determination of salt iodine level:

- The expiry dates of the rapid kits were checked before the beginning of the study.
- The field workers were trained by the researcher on the use of rapid kits following the standardised procedures available on the test kits covers (same procedure for all the kits). They were given time during the training period to practice and the results obtained between them were compared before the beginning of the study to obtain better consistency in the results
- The pilot study was done to practice using the kits, to check that instructions were clear, to discuss problems that may be encountered during the fieldwork and to compare the results obtained between the field workers.
- The "control" salt sample was tested before testing the children's samples at each testing site when each kit was opened.
- The measuring spoon and test plate were wiped clean between each sample testing.
- Field workers were supervised by the researcher during salt testing

8.1.3.4 The cut-off points

The cut-off level to define adequately iodised salt at household level has recently been revised to 15ppm (WHO/UNICEF/ICCIDD, 1999). However, during the time of this study the newly developed test kits, which estimate salt iodine levels at concentrations 0, <15 and >15ppm were not available in the country, therefore, estimates will be based on 20ppm, which was previously used to define adequately iodised salt at household level. The rapid tests in the study were, however, used qualitatively.

8.1.4 Iodised oil capsule supplementation

8.1.4.1 Theoretical procedure for obtaining information

Data collection techniques include using available information, observing, interviewing and administering written questionnaires. Administering written questionnaires is less expensive, permits anonymity and may result in more honest responses. It also eliminates bias due to phrasing questions differently with different respondents (Katzenellenbongen *et al.*, 1991, p.27). A questionnaire can be self-administered, structured or unstructured. In a structured interview, questions are asked in the same way with the same probes, clarifications and recording is uniform.

The following measures should be followed to improve accuracy of questionnaires:

- Prepare field work manual for the research team
- Select field workers with care
- Train field workers on interviewing techniques and how to fill questionnaire
- Pre-test the questionnaire
- Take care field workers are not placed under too much stress
- Arrange for ongoing supervision

8.1.4.2 Study procedures for obtaining information on iodised oil supplementation

A structured questionnaire (Appendix 11), which generated information on age, sex, thyroid size and whether the child received capsules in 1995 to 1996 or in 1997 to 1998 or both periods, was administered to the children aged 8 to 12 years. This questionnaire was used to estimate a number of children (8-12 years) who received iodised oil capsules in 1995-1996 and in 1997-1998. Each of these capsules contained 200mg of iodine.

The following measures were followed to obtain information on iodised oil supplementation:

- Selection of field workers was based on profession and experience.
- The field workers were trained on the purpose and procedure of the study and on interviewing techniques.
- The questionnaire was pre-tested before fieldwork.
- To avoid stress, three field workers interviewed the children and one field worker did not interview more than 50 children in each school. Not more than 2 schools were visited each day.
- The "Bukana" were used to verify information on iodised oil capsule supplementation. The information from each child was double checked with the class teacher, who referred to the school record book on age and iodised oil capsule supplementation.
- Questions were asked in the same way with the same probes and clarifications and recording was uniform.
- The field workers were supervised by the researcher during interviews.
- The questionnaires were edited after every visit by the supervisor (researcher), who made sure that each question was properly answered.

- The interviews were conducted in the home language of the children (Sesotho).

8.2 CALCULATIONS

8.2.1 The prevalence of goitre

This refers to the total number of primary school children aged 8 to 12 years with goitre over the total number of primary school children included in the study. The prevalence of goitre was determined using the goitre grades obtained during palpation.

The following WHO/UNICEF/ICCIDD (1994) cut-off points were used to assess the severity of IDD using the prevalence of goitre

Severity of IDD	Mild IDD	Moderate IDD	Severe IDD
Prevalence of goitre (TGR)	5.0-19.9%	20.0-29.9%	>/= 30.0%

8.2.2 Iodised oil supplementation coverage

This refers to the percentage of primary school children aged 8 to 12 years who received iodised oil capsules during 1995 to 1996 and in 1997 to 1998. This information was obtained from the structured questionnaire administered to all children aged 8 to 12 years in each school.

According to WHO/UNICEF/ICCIDD (1994), coverage is adequate when more than 95 percent (>95%) of at risk population have received iodised oil annually.

8.2.3 Salt iodisation coverage

This refers to the percentage of households using adequately iodised salt. The WHO/UNICEF/ICCIDD (1994) criteria for use as core indicator in monitoring progress towards the goal of eliminating IDD as a significant public health problem is that the proportion of households consuming adequately iodised salt should be greater than 90 percent (>90%). Rapid test, which is qualitative, was used in the present study instead of titration method, which is quantitative. The results obtained were used to obtain only the percentage of households with iodised salt and those with non-iodised salt. Therefore coverage on the use of adequately iodised salt was not determined.

9. STUDY PROCEDURES

9.1 LOGISTICS

Before visiting the schools the following points were considered:

- Copies of the proposal and covering letters were sent to the Ministry of Education and Ministry of Local Government for approval. After the approval, official letters were then sent to the principals and chiefs of the selected schools, which notified them on the purpose, date of the visit and what was expected. They were also kindly asked to pass the message to the children and parents.
- Copies of the consent forms written in Sesotho and in English (Appendix 9) were also sent to all the principals for parents or guardians to sign for approval this were then kept at schools until the day of the visit.
- After the official letters were sent, messages were passed through the local radios and they included the purpose, dates and what the children had to bring with them on the date of the visit. All children

were asked to bring their health booklets (Bukana) and a sample of salt used in their households.

9.2 FIELD PROCEDURES

The procedures followed for each school during the study were as follows:

- Schools were visited during the morning hours (8:00 a.m - 12:00 a.m). The field workers stayed at a chosen centre and travelled daily to the schools.
- Using the enrolment lists in each school, children aged 8 to 12 years were selected. The total number of children in the school and the number of absent children who fall under the selected age group were obtained from the teachers and some children were excluded based on the exclusion criteria.
- The purpose and procedure of the study were explained in detail to the selected children. The children were then asked to sign (signature of a cross for those who did not know how to write) the consent forms (previously signed by parents or guardians), which was read and explained by the interviewer using home language.
- Goitre size was assessed using the palpation method and each child (8-12 years) was palpated according to the standardised procedures for palpation and the size graded separately by one nurse and one nutritionist. When the estimates did not agree, the lowest score was chosen.
- The salt samples brought by the children (8-12 years) were analysed for the level of iodine using the rapid tests following the procedures available on the test kits covers.
- A questionnaire, which generated information on age, sex, goitre grade, level of iodine in salt and the year in which iodised oil capsule was received was asked by the interviewer in the presence of the class teacher. The "Bukana" were used to verify information on iodised oil capsule supplementation. The class teacher assisted

by checking from the enrolment list and school record book, the ages of the children and the years in which capsules were received.

- Simple random sampling was used to select 10 children to give urine samples not less than 10ml (more than half of the given bottle for urine collection). All the children aged 8 to 12 years were given numbers starting from 1. These numbers were written on each child's hand using a marking pen. 10 numbered pieces of papers were drawn from a box and the children whose numbers corresponded to the selected numbers were to give urine samples. After sample collection, the plastic bottle containers were sealed and identified with labels indicating the identification code of the subject, school and the district. The sealed containers were then kept in cooler boxes, which were transferred to the central laboratory at Queen II hospital where they were refrigerated before taken for analysis.

10. STATISTICAL ANALYSIS

The statistical analysis of the results was done by the Department of Biostatistics of the University of Orange Free State. The SAS package version 6 was used for analysis (Cary NC: SAS® producers guide, version 6, third edition, 1990).

Results were summarised by frequencies and percentages for categorical variables and 25th percentiles, medians and 75th percentiles for numerical variables. To calculate the prevalence for the country as a whole, district and ecological zone-specific rates were adjusted using the total number of children per districts and ecological zones as indicated in Table 7. The weights used for the adjustment for the country as a whole, the zones and the districts are given in Appendix 12. The Cochran-Mantel-Haenzel test was used to assess the statistical significance of the associations and the Kruskall-Wallis test for differences in medians.

11. PROBLEMS ENCOUNTERED

The following problems were encountered during the study. These problems were however solved and all data were collected as required:

- It was difficult for younger children to remember their ages and when the capsules were received, so the interviewer consumed more time to gather all information required by finding the correct information with the help of teachers from the enrolment list and school record books.

- The study was done during examination time and these inconvenienced all the groups involved. Some times the fieldworkers had to wait for the children to finish writing and this prolonged the time for data collection and in some cases the children started writing their examinations later than it was scheduled.

- Some children were not able to give urine after being selected therefore another selection had to be done to replace that child. That is, another numbered piece of paper was drawn from the box.

12. CONCLUSION

The design and sample size for this study were adequate to give representative results. Validity and reliability of methods were ensured therefore quality data were obtained from the results of this study.

CHAPTER 4

RESULTS

1. INTRODUCTION

In this chapter, the results of the study are presented in tables with a short discussion of each. The results on sample size, urinary iodine concentration, prevalence of goitre, iodised oil supplementation and salt iodisation level will be presented at national level, by districts and ecological zones. Except for the medians the results were adjusted proportional to the size of the districts and ecological zones.

2. SAMPLE SIZES

2.1 SAMPLE SIZE AT NATIONAL AND DISTRICT LEVEL

Table 7 gives the total number of children who responded to the questionnaire (Appendix 11) and palpated for thyroid size. Table 8 also gives the number of children in each age group, the number of salt samples tested and urine samples collected in each district and for the whole country. The total number of children who responded to the questionnaire is 4071 with 100 percent response rate. All of these children were in the age group 8 to 12 years. Urine samples were collected from 50 children in each district resulting in 500 children for the whole country.

The number of children palpated for thyroid size in each district ranged from 369 (Quthing district) to 452 (Thabatseka district). A total of 4071 children, 2335 females and 1736 males were palpated for thyroid size. Each of these children brought salt samples from their households

therefore, 4071 salt samples were tested for iodine level. There were more females than males in all the districts except for Qacha's Nek district (49.5% females and 50.5% males). The larger proportion (24.4%) of the children was aged 10 years and a smaller proportion (14.9%) of the children were aged 8 years.

Table 7. The sample size at national and district level

Districts	Number of children who responded to questionnaire, and were palpated for thyroid size			Number of salt samples tested (n)	Number of urine samples analysed (n)
	Sex		Age		
	(n)	(%)	(Years; %)		
Thabatseka	F 266 M 186 **T 452**	58.8 41.2	8: 15.3 9: 21.5 10: 23.2 11: 21.2 12: 18.2	452	50
Leribe	F 277 M 161 **T 438**	63.2 36.8	8: 16.4 9: 17.6 10: 24.4 11: 22.4 12: 19.2	438	50
Maseru	F 294 M 144 **T 438**	67.1 32.9	8: 11.6 9: 16.7 10: 28.3 11: 25.8 12: 17.6	438	50
Mokhotlong	F 231 M 182 **T 413**	55.9 44.1	8: 17.2 9: 19.6 10: 24.0 11: 23.0 12: 16.2	413	50
Buthabuthe	F 200 M 197 **T 397**	50.4 49.6	8: 11.8 9: 19.1 10: 20.9 11: 22.9 12: 25.9	397	50

Mohaleshoek	F 228 M 150 **T 378**	60.3 39.7	8: 13.8 9: 17.2 10: 27.8 11: 17.2 12: 24.1	378	50
Berea	F 195 M 178 **T 373**	52.3 47.7	8: 13.9 9: 22.8 10: 24.7 11: 19.8 12: 18.8	373	50
Quthing	F 211 M 158 **T 369**	57.2 42.8	8: 14.9 9: 15.7 10: 24.9 11: 23.6 12: 20.9	369	50
Qacha's Nek	F 187 M 191 **T 378**	49.5 50.5	8: 14.6 9: 15.1 10: 28.3 11: 20.6 12: 21.4	378	50
Mafeteng	F 246 M 189 **T 435**	56.6 43.4	8: 19.3 9: 13.3 10: 17.9 11: 28.5 12: 20.9	435	50
TOTAL	**F 2335** **M 1736** **T 4071**	**57.4** **42.6**	**8: 14.9** **9: 17.9** **10: 24.4** **11: 22.6** **12: 20.2**	**4071**	**500**

F= FEMALE, M=MALE and T=TOTAL

2.2 SAMPLE SIZE IN EACH ECOLOGICAL ZONE

The total number of children who participated in all the ecological zones in each district is given in Appendix 13. Table 8 shows that a large number of the primary school children included in the sample were from the Mountains (1797). Similar to the results obtained from each district, the number of females in each zone was higher than the number of males.

The percentage of children aged 8 years was higher in the Lowlands (19%) compared to the Mountains (10.5%).

Table 8. Sample size per ecological zone

Ecological Zones	Sex (n)		Percentage of children in each age group					Total (n)
	M	F	8	9	10	11	12	
Mountains	724	1073	10.5	11.3	28.4	28.6	28.6	**1797**
Lowlands	392	396	19.0	18.8	22.3	16.8	16.8	**788**
Foothills	284	430	13.2	19.6	22.3	21.0	21.0	**714**
Senqu River Valley	336	436	16.9	21.9	24.6	22.2	14.4	**772**
Total	**1736**	**2335**	**14.9**	**17.9**	**24.4**	**22.6**	**20.2**	**4071**

3. URINARY IODINE CONCENTRATION

The median urinary iodine concentration and the distribution of urinary iodine levels in categories showing the severity of iodine deficiency according to WHO/UNICEF/ICCIDD (1999) draft report are presented in this section. These results are presented at national and district level as well as by ecological zones.

3.1 THE MEDIAN URINARY IODINE CONCENTRATION AT NATIONAL AND DISTRICT LEVEL

The analysis of the urine samples showed that the median urinary excretion level at national level was 26.3µg/l (Table 9) indicating moderate IDD according to WHO/UNICEF/ICCIDD (1999) draft report. There was no difference in the urinary iodine levels of females (26.2µg/l) and males (26.4µg/l). The median urinary iodine concentrations ranged

from 22.3μg/l (Thabatseka) to 47.9μg/l (Berea) in the different districts (Kruskall-Wallis $p<0.001$), which also indicate moderate IDD.

Table 9. The median urinary iodine concentration at national and district level

Districts	N	Median urinary iodine concentration (μg/l)
Thabatseka	50	22.3
Leribe	50	25.2
Maseru	50	24.2
Mokhotlong	50	27.3
Buthabuthe	50	24.6
Mohaleshoek	50	36.7
Berea	50	47.9
Quthing	50	26.4
Qacha's Nek	50	24.2
Mafeteng	50	26.4
Total	**500**	**26.3**

3.2 THE MEDIAN URINARY IODINE CONCENTRATION BY ECOLOGICAL ZONES

According to Table 10 iodine deficiency as represented by urinary iodine excretion in the Mountains (25.7μg/l) and in the Lowlands (27.2μg/l) showed no significant difference (Kruskall-Wallis $p=0.052$). The results in Table 10 also indicate moderate IDD in all the ecological zones according to WHO/UNICEF/ICCIDD (1999) draft report.

Table 10. The median urinary iodine concentration by ecological zones

Ecological zones	n	Median urinary iodine concentration (µg/l)
Mountains	200	25.7
Lowlands	110	27.2
Foothills	90	26.2
Senqu River Valley	100	26.4
Total	**500**	**26.3**

3.3 CATEGORIES OF URINARY IODINE CONCENTRATIONS AT NATIONAL AND DISTRICT LEVEL

Table 11 shows that the urinary iodine concentration of all the children were in the severe to mild range of iodine deficiency and none in the adequate iodine intake range (>100 µg/l). The urinary iodine concentration of 11.3 percent of the children, were in the severely deficient range (<20µg/l), 82.6 percent in the moderate range (20-49µg/l) and 6.1 percent in the mild range (50-99µg/l) of iodine deficiency. 93.9 percent (82.6%+11.3%) of the children showed urinary iodine excretion lower than 50µg/l, which is used as criteria for monitoring progress towards eliminating IDD as a public health problem.

None of the urinary iodine levels of the children in Mohaleshoek and Berea districts and 36.4 percent in Thabatseka district were in the severely deficient range. None of the children in the four districts; Thabatseka, Leribe, Mokhotlong and Mafeteng and 21.8 percent of the children in Berea district had urinary iodine concentrations in the mild range of iodine deficiency. There were significant differences between districts (Mantel-Haenszel $p<0.001$).

Table 11. Categories of urinary iodine concentrations at national and district level

Districts	Percentage of children in each urinary iodine concentration category (μg/l)					
	<20 severe IDD	20-49 moderate IDD	50-99 mild IDD	100-199 Adequate Iodine Intake	200-300 More than adequate intake	>300 Excessive iodine intake
Thabatseka	36.4	63.6	0	0	0	0
Leribe	20.3	79.7	0	0	0	0
Maseru	4.1	80.1	15.7	0	0	0
Mokhotlong	12.3	87.7	0	0	0	0
Buthabuthe	4.0	94.6	1.4	0	0	0
Mohaleshoek	0	95.4	4.6	0	0	0
Berea	0	78.2	21.8	0	0	0
Quthing	3.4	95.6	1.0	0	0	0
Qacha's Nek	25.7	72.3	2.0	0	0	0
Mafeteng	8.3	91.7	0	0	0	0
Adjusted total	**11.3**	**82.6**	**6.1**	**0**	**0**	**0**

3.4 CATEGORIES OF URINARY IODINE CONCENTRATION BY ECOLOGICAL ZONE

Table 12 shows that 17.7 percent of the children in the Mountains and 1.9 percent of the children in the Lowlands were in the severely deficient range. Table 12 also shows that 1.4 percent of the children in the Mountains and 23.3 percent of the children in the Lowlands were in the mild range of iodine deficiency. These results indicate that iodine deficiency is higher in the Mountains than in the Lowlands (Mantel-Haenszel $p<0.001$).

Table 12. The distribution of iodine deficiency by ecological zones

Ecological zones	Percentage of children in each urinary iodine concentration category (μg/l)					
	<20 Severe IDD	20-49 Moderate IDD	50-99 Mild IDD	100-199 Adequate iodine intake	200-300 More than adequate iodine intake	>300 Excessive iodine intake
Mountains	17.7	80.0	1.4	0	0	0
Lowlands	1.9	77.2	23.2	0	0	0
Foothills	14.2	81.6	15.6	0	0	0
Sengu river valley	10.8	84.1	4.2	0	0	0
Adjusted total	11.3	82.6	6.1	0	0	0

4. THE PREVALENCE OF GOITRE

The prevalence of goitre will be presented in this section at national and district level as well as by ecological zones, age and gender. The size of the thyroid gland of each child was visually inspected and palpated and was graded according to the criteria of the WHO/UNICEF/ICCIDD (1994). The prevalence of goitre (Goitre rate) included the rate of palpable or visible goitre.

4.1 THE ADJUSTED PREVALENCE OF GOITRE AT NATIONAL AND DISTRICT LEVEL

The thyroid size presented in Table 13 indicates that only grade 0 (no palpable goitre) and grade 1 (palpable but non visible goitre) were prevalent in the whole country and in all the districts. There was no grade 2, which is visible goitre in all the children palpated. A higher percentage of grade 0 goitre and a lower percentage of grade 1 goitre were found in

Quthing district (97.8% and 2.2% respectively). The adjusted percentage for the whole country was 95.1 percent for grade 0 goitre and 4.9 percent for grade 1 goitre.

The adjusted prevalence of goitre for the whole country was 4.9 percent. This prevalence ranged from 2.2 percent (Quthing) to 8.8 percent (Thabatseka and Mohaleshoek) in the different districts (Mantel-Haenszel $p<0.001$).

Table 13. The adjusted prevalence of goitre at national and district level

Districts	Percentage of children according to goitre grade			The adjusted prevalence of goitre (%)
	0	1	2	
Thabatseka	91.2	8.8	0	8.8
Leribe	95.3	4.7	0	4.7
Maseru	97.3	2.7	0	2.7
Mokhotlong	93.0	7.0	0	7.0
Buthabuthe	92.3	7.7	0	7.7
Mohaleshoek	91.2	8.8	0	8.8
Berea	96.3	3.7	0	3.7
Quthing	97.8	2.2	0	2.2
Qacha's Nek	94.8	5.2	0	5.2
Mafeteng	97.5	2.5	0	2.5
ADJUSTED TOTAL	**95.1**	**4.9**	**0**	**4.9**

4.2 THE ADJUSTED PREVALENCE OF GOITRE BY ECOLOGICAL ZONES

According to Table 14 it is clear that iodine deficiency as represented by the prevalence of goitre is higher in the Mountains (6.3%) and Foothills (6.0%) than in the Lowlands and Senqu river valley (2.3%) (Mantel-Haenszel $p=0.007$).

Table 14. The adjusted prevalence of goitre by ecological zones

Ecological zones	The adjusted goitre prevalence (%)
Mountains	6.3
Lowlands	2.3
Foothills	6.0
Sengu River Valley	2.3

4.3 THE ADJUSTED PREVALENCE OF GOITRE BY AGE

Table 15 clearly indicates that the prevalence of goitre increased with age (Mantel-Haenszel $p<0.001$). Goitre prevalence of the 8 and 9 years old children was 3.0 percent and increases from 6.0 to 6.3 percent in children aged 10 to 12 years.

Table 15. The adjusted goitre prevalence by age

Age (years)	Adjusted prevalence of goitre (%)
8	3.0
9	3.0
10	6.0
11	6.1
12	6.3

4.4 THE ADJUSTED PREVALENCE OF GOITRE BY GENDER

In all the districts the prevalence of goitre was higher in females than in males but these differences were significant only in Mokhotlong and Buthabuthe (Table 16). For the whole country the adjusted goitre prevalence for females was 5.4 percent and 4.5 percent for males. A

sharp contrast between the prevalence of goitre in females and males was seen in the four districts, Leribe, Mokhotlong, Quthing and Mafeteng.

Table 16. The adjusted goitre prevalence by gender at national and district level

Districts	Adjusted goitre prevalence (%)		p-value
	Females	Males	
Thabatseka	10.3	7.8	0.137
Leribe	8.0	3.1	0.074
Maseru	3.6	1.9	0.862
Mokhotlong	10.1	3.4	0.007
Buthabuthe	10.5	5.2	0.045
Mohaleshoek	10.6	5.8	0.371
Berea	4.7	3.2	0.671
Quthing	3.7	1.7	0.093
Qacha's Nek	5.8	4.9	0.537
Mafeteng	3.9	1.1	0.249
Adjusted total	**5.4**	**4.5**	

Similar to the prevalence of goitre in the different districts, the adjusted goitre prevalence in each of the four ecological zones tended to be higher in females than in males but this was not statistically significant (Table17).

Table 17. The Adjusted goitre prevalence by gender in each ecological zone

Ecological zones	Prevalence of goitre (%)		p-value
	Females	Males	
Mountains	7.1	5.4	0.062
Lowlands	3.3	1.3	0.159
Foothills	6.8	5.3	0.512
Senqu River Valley	3.3	1.9	0.958
Adjusted total	**5.4**	**4.5**	

5. IODISED OIL SUPPLEMENTATION

This section demonstrates the number of children who received iodised oil capsules during the first supplementation in 1995 to 1996 (only in 1995/96) and during the second supplementation in 1997 to 1998 (only in 1997/98). It also shows the number of children who received iodised oil capsules during both the first and second supplementation indicating supplementation coverage. The number of children who never received iodised oil capsules is also shown in this section. All children brought their "Bukana" and the information about the taking of the capsules was taken from the "Bukana".

5.1 IODISED OIL SUPPLEMENTATION AT NATIONAL AND DISTRICT LEVEL

Table 18 shows that 68.5 percent (13.4% + 55.1%) of children received capsules during the first supplementation (1995-1996), 67.8 percent (12.7% + 55.1%) received capsules during the second supplementation (1997-98) and 55.1 percent received capsules during both the first and second supplementations (in 1995/96 and in 1997/98). 18.9 percent of

children never received supplementation. From the children who only received capsules in 1995 to 1996 and in 1997 to 1998, the highest percentages were from Leribe (43.4%) and Maseru (28.1%) districts. The lowest percentage (5.5%) of children who received capsules in both years and the highest percentage (38.0%) of children who never received capsules were from Thabatseka district. There were significant differences between the districts (Mantel-Haenszel p<0.001).

Table 18. Iodised oil supplementation at national and district level

Districts	Percentage of children who received iodised oil capsules			Percentage of children who did not receive iodised oil capsules
	1995/96 &1997/98	Only in 1995/96	Only in 1997/98	
Thabatseka	5.5	43.2	13.3	38.0
Leribe	40.4	43.4	4.4	11.7
Maseru	53.5	6.6	28.1	11.8
Mokhotlong	80.1	4.8	6.6	8.6
Buthabuthe	69.2	1.3	11.3	18.3
Mohaleshoek	69.0	1.5	4.3	25.1
Berea	66.0	1.5	8.8	23.7
Quthing	70.4	1.0	11.6	17.1
Qacha's Nek	71.0	0.1	2.7	26.2
Mafeteng	67.8	1.5	11.7	18.9
Adjusted percentage	**55.1**	**13.4**	**12.7**	**18.9**

5.2 IODISED OIL SUPPLEMENTATION COVERAGE BY ECOLOGICAL ZONES

Table 19 indicates that a higher supplementation coverage was achieved in the Lowlands (71%) than in the Mountains (41%). Of the children who never received iodised oil capsules the largest percentage (25.4%) was found in the Mountains while the smallest percentage (10.9%) was found in the Lowlands (Mantel-Haenszel p<0.001).

Table 19. Iodised oil supplementation per ecological zone

Ecological zones	Percentage of children who received iodised oil capsules			Percentage of children who never received iodised oil capsules
	Both in 1995/96 and 1997/98	Only in 1995/96	Only in 1997/98	
Mountains	41	15.1	18.2	25.4
Lowlands	71	10.3	7.6	10.9
Foothills	70	2.7	14.2	12.4
Senqu River Valley	55	19.5	6.9	18.4
Adjusted total	**55.1**	**13.4**	**12.7**	**18.9**

6. SALT IODISATION

The level of iodine in salt was tested using the rapid test kits. These test kits estimate salt iodine concentrations at 0ppm, 25ppm, 50ppm, 75ppm and 100ppm. This test method is internationally regarded as inaccurate therefore data obtained from these results will only be used qualitatively. This section shows the iodine content of salt samples brought by school children and the number of school children using iodised salt at household level.

6.1 SALT IODINE CONTENT AT NATIONAL AND DISTRICT LEVEL

Table 20 indicates that 94.8 percent of salt samples were iodised (>0 ppm). Most of the salt samples (73.5%) had iodine content of 50ppm and more. Of the salt samples that were not iodised the highest percentage (11.9%) was from Thabatseka district and the lowest percentage (1.5%)

was from Berea district. There were significant differences between the districts (Mantel-Haenszel p<0.001).

Table 20. Iodine content of salt at national and district level

District	**Percentage of salt samples at different iodine concentrations**				
	0	**25**	**50**	**75**	**100**
Thabatseka	11.9	28.9	42.9	16.0	0.3
Leribe	8.0	25.2	49.8	17.0	0
Maseru	2.5	21.4	48.0	28.1	0
Mokhotlong	6.7	21.1	50.3	21.9	0
Buthabuthe	1.6	16.8	47.1	34.5	0
Mohaleshoek	4.3	16.5	51.8	27.4	0
Berea	1.5	17.6	48.9	32.0	0
Quthing	4.9	19.9	52.2	23.0	0
Qacha's Nek	8.5	21.0	44.9	25.7	0
Mafeteng	3.0	17.5	57.4	21.5	0
Adjusted percentage	**5.2**	**21.2**	**49.1**	**24.4**	**0**

6.2 SALT IODINE CONTENT BY ECOLOGICAL ZONES

Non-iodised salt as indicated in Table 21 was used mostly in the Mountains (7.6%) and less in the Lowlands (1.8%) (Mantel-Haenszel p=0.004).

Table 21. Iodine content of salt by ecological zones

Ecological zones	Percentage of salt samples at different iodine concentrations				
	0	25	50	75	100
Mountains	7.6	21.8	48.1	22.4	0.1
Lowlands	1.8	21.1	50.0	27.4	0
Foothills	5.4	20.9	49.2	24.3	0
Senqu river valley	3.6	20.9	50.2	25.2	0
Adjusted Total	**5.2**	**21.2**	**49.1**	**24.4**	**0**

7. THE ASSOCIATIONS BETWEEN THYROID SIZE, URINARY IODINE, IODISED SALT AND IODISED OIL SUPPLEMENTATION

Iodised salt introduction as a long-term intervention and iodised oil supplementation as a short-term intervention have been used in eradicating IDD in many countries. The contribution of these interventions on IDD status in Lesotho will be indicated in this section. The Cochran-Mantel-Haenszel test was used to test for the associations between iodised salt and both urinary iodine concentration and thyroid size and between iodised oil supplementation and thyroid size.

7.1 THE ASSOCIATION BETWEEN THE LEVEL OF IODINE IN SALT AND THE URINARY IODINE CONCENTRATION

Table 22 shows that urinary iodine concentration slightly increased with an increase in salt iodisation level. This association is however not statistically significant (p=0.902). Of the children who had urinary iodine concentrations in the severe range of IDD, 20 percent used non-iodised

salt and 7.4 percent used salt with iodisation level of 75ppm. Similarly, of the children who had urinary iodine concentrations in the mild range of IDD, none used non-iodised salt and 9.8 percent used salt with iodisation level of 75ppm. However the median urinary iodine concentration of the children with different salt iodine content showed no difference.

Table 22. The association between salt iodisation level and urinary iodine concentration

Salt iodine Content (ppm)	Percentage of children in each urinary iodine concentration category			The median urinary Iodine (μg/l)
	0-19 Severe IDD	20-49 Moderate IDD	50-99 Mild IDD	
0	20.0	80.0	0	25.2
25	11.1	85.9	3.0	26.4
50	10.2	85.0	4.9	26.2
75	7.4	82.8	9.8	26.4
100	100	0	0	18.4

7.2 THE ASSOCIATION BETWEEN SALT IODINE CONTENT AND GOITRE GRADE

Table 23 indicates that of the children who used non-iodised salt 14.2 percent had grade 1 goitre and 5.2 percent had grade 0 goitre. This association, which was found to be statistically significant (p=0.001), shows that thyroid size decreased with an increase in salt iodisation.

Table 23. The association between salt iodine level and goitre grade

Goitre grade	Percentage of children with different iodine content of salt				
	0	25	50	75	100
0	5.2	18.9	50.2	25.8	0
1	14.2	39.2	43.9	2.8	0

7.3 THE ASSOCIATION BETWEEN IODISED OIL SUPPLEMENTATION AND GOITRE GRADE .

Table 24 shows that of the of the children who had capsules both times, that is, during 1995 to 1996 and during 1997 to 1998, 5.0 percent had grade 1 goitre and of those who never received capsules, 6.4 percent had grade 1 goitre. The results in Table 24 also show that goitre size slightly decreases with iodised oil supplementation. This slight decrease is however not statistically significant (p=0.685).

Table 24. The association between iodised oil supplementation and goitre grade

Years reported for supplementation	Percentage of children with grade 1 goitre
1995 to 1996 only	4.9
1997 to 1998 only	4.9
1995 to 1996 and 1997 to 1998	5.0
No capsules received	6.4

7.4 THE ASSOCIATION BETWEEN URINARY IODINE AND GOITRE

Table 25 shows that of the children, who were in the moderate range of iodine deficiency according to urinary iodine excretion, few had goitre and of the children who were in the mild range, non had goitre. This association was however not statistically significant (Mantel-Haenszel p=0.246).

Table 25. The association between urinary iodine and goitre

Categories of urinary iodine (µg/l)	Percentage of children with goitre
0-19	2.0
20-49	5.8
50-99	0.0

8. SUMMARY OF THE RESULTS

It was observed in this study that the median urinary iodine concentration was 26.3 µg/l. The urinary iodine excretion of all the children, were in the severe (11.3%) to mild (6.1%) range of iodine deficiency with a high proportion (82.6%) in the moderate range. The prevalence of goitre obtained from only grade 1 goitres was 4.9 percent. The goitre prevalence increased with age and was higher in females (5.6%) than males (4.3%). Iodine deficiency indicated by both urinary iodine excretion and the prevalence of goitre was higher in the Mountains and lower in the Lowlands than in other zones. Coverage on the use of iodised oil supplementation (55.1%) was not adequate, while 94.8 percent of the households use iodised salt. Thyroid size was found to decrease with an increase in salt iodine content. Although statistically not significant there was also a slight increase in urinary iodine concentration with an increase in salt iodine content and a slight decrease in thyroid size with iodised oil supplementation.

CHAPTER 5

DISCUSSION

1. INTRODUCTION

One of the fundamental purposes of IDD surveillance is to determine the magnitude and distribution of IDD within a population (WHO/UNICEF/ICCIDD, 1994). This assessment can provide a baseline for long-term monitoring, serve as an advocacy tool to highlight the extent of IDD problems and stimulate action including the appropriate allocation of resources for eliminating IDD. A variety of target groups might serve as the focus for IDD surveillance but observing school children preferably aged 6 to 12 years is the usual strategy with advantages of access and convenience and this has been used extensively in most surveys (WHO/UNICEF/ICCIDD, 1994).

The main objective of this study was to assess the urinary iodine and goitre status of the primary school children in Lesotho five years after the 1993 National micronutrient survey, which indicated a high prevalence of IDD. The previous use of iodised oil capsules as a short-term intervention and current use of iodised salt as a long-term intervention and the effectiveness of these interventions in eliminating IDD were also assessed.

In this chapter the important observations from the results on the urinary iodine concentration, thyroid size, prevalence of goitre, iodised oil capsule supplementation and salt iodisation will be discussed. The small sample size for median urinary iodine determination and rapid test, which was the method used for testing the iodine content of salt samples will also be discussed under relevant sections as possible limitations to the study.

2. SAMPLE SIZES

The sample size was not proportionally drawn therefore values had to be weighed. It was, however, easy to weigh the percentages but difficult to weigh the median values for urinary iodine concentration. Therefore all the results except for the medians were adjusted proportional to the size of the country, districts and ecological zones.

The primary school children are a convenient test group because of accessibility (Dunn & Van der Haar, 1990, p.24). They reflect the current status of iodine nutrition in the community and are a major priority for prompt correction of IDD. Accordingly school children were selected as a target population in the present study. A potential disadvantage to the use of this group is that children from the most disadvantaged communities may not attend school (Department of Health in South Africa, 2000).

According to WHO/UNICEF/ICCIDD (1994), children between the ages of 6 to 12 years should preferably be studied. Slightly different from the recommendations, children aged 8 to 12 years were studied in the present study. This was done to eliminate measurement error as it has been documented that the smaller the child, the smaller the thyroid and the more difficult it is to perform palpation (WHO/UNICEF/ICCIDD, 1994; Stanbury, 1994, p.43).

The higher number of females than males observed in this study may be attributed to the nationwide high ratio of females to males as indicated in all of Lesotho census documents available at the Lesotho Bureau of Statistics. It may also be possibly to the fact that male children normally go to look after animals (work as herd boys) especially in the rural areas therefore depriving them of education. The issue of depriving male children of education was also discussed in a 1990 study when it was

estimated that the literacy rate in Lesotho is 6 percent of which 70 percent are females and 40 percent are males (UNICEF- Lesotho, 1990).

The reasons for the small percentage of children aged 8 years observed in the whole country are not known. One possible reason would, however, be that some children do not go to primary schools at early ages because of the long walking distances to some of the schools especially in the Mountains. This possible reason was confirmed by the results of the present study, which indicated that a smaller percentage of school children aged 8 years, was found in the Mountains than in the other zones.

3. URINARY IODINE

For nearly half a century, the benchmark method for determining the state of iodine nutrition has been the measurement of the excretion of iodine in the urine (Stanbury & Pinchera, 1994, p.34). This is because 80 to 95 percentage of the daily intake of ingested iodine is excreted in the urine (Delange, 1994). Therefore measurement of urinary excretion is considered the best indicator of IDD in a population as long as the method used is valid and reliable. In the present study, the method used was based on literature to ensure validity and reliability of the results (Aumont & Tressol, 1986; WHO/UNICEF/ICCIDD, 1994; May & May, 1998).

The 24 hour urinary iodine excretion is normally considered to be the best measure of iodine status in an individual (Rasmussen *et al.*, 1999). However iodine content of foods varies considerably with relatively few foods having a high content of iodine. Therefore the intake of iodine will vary greatly from day to day and likewise, the daily iodine excretion is expected to vary. In Denmark, it was found that the individual iodine excretion varied considerably from one day to another and during the day and therefore it was concluded that for determination of iodine status in an individual, more than one 24-hour urine samples must be used

(Rasmussen *et al.*, 1999). It was, however, shown in the same study that even in highly motivated people it is difficult to get complete 24-hour urine samples and it was suggested that casual urine samples be taken at any time during the day except as morning fasting urine.

While it is not generally possible to obtain 24-hour samples of urine, measurement of concentration in a casual sample from 40-50 subjects is an excellent surrogate (Stanbury & Pinchera, 1994, p.25). It is also stated that since individual's urinary iodine levels vary from day to day, values can only be used for a population estimate (Benade *et al.*, 1997). Therefore based on the above literature, casual urine samples were collected to estimate iodine excretion of the primary school children in Lesotho.

There are many different urinary iodine methods available which range from technically sophisticated techniques to simple manual techniques with limited instrumentation requirements. These methods have been compared and each has its own advantages and limitations. The Sandell-Kolthoff reaction with some prior step involving ashing or digestion is usually the most practical approach for laboratory determination of urinary iodine (Dunn *et al.,* 1993; May, 1998). For this reason, the Sandell-Kolthoff reaction, which involved alkaline ashing was used in the present study to determine urinary iodine levels.

The optimal means for expressing urinary iodine in casual urine samples has received much scrutiny (Bourdoux *et al.*, 1993). Many investigators have measured creatinine and iodine in the same urine samples and expressed the iodine as micrograms per gram creatinine. These calculations assume that individuals excrete a constant amount of creatinine in the urine each day, usually related to size, sex and muscle mass. Most field studies in past decades have used this means of expressing urinary iodine.

More recently it was recommended that urinary iodine can be expressed as concentration (µg/l) rather than relating it to creatinine based on the fact that creatinine excretion can vary considerably among individuals and among population groups as well as in the same individual at different times (Bourdoux, 1993; Thompson, 1997). Furthermore, lower creatinine excretions frequently occur in areas of malnutrition, which is the problem in most developing countries. In addition to being more reliable than the relationship of iodine to creatinine, the expression of iodine as a concentration is obviously simpler, because only a single determination for iodine is necessary rather than the two for iodine and creatinine. The urinary iodine values from populations are not normally distributed so it is recommended that the median values be used for interpretation of the results (May & May, 1998). Based on the above studies, the urinary iodine excretion in the present study was expressed as µg/l using the median values.

The median urinary excretion for the whole country in the present study was 26.3µg/l, which according to WHO/UNICEF/ICCIDD (1999) draft report indicates moderate iodine deficiency. The median urinary excretion, which ranged from 22.3µg/l to 47.9µg/l and from 25.7µg/l to 27.2µg/l in the different districts and ecological zones respectively, also indicated moderate iodine deficiency. The analysis of the distribution of the data showed values below 100µg/l in all the children (100%) and 93.9 percent of the children had urinary iodine excretion below 50µg/l. These values are extremely higher than 50 percent and 20 percent respectively which are used as criteria for monitoring progress towards eliminating IDD as a public health problem. The results of the present study, therefore, indicate that IDD is still a public health problem in Lesotho.

The urinary iodine excretion in the Mountains (25.7µg/l) and Lowlands (27.2µg/l) in the present study is low compared to the national study conducted by the Ministry of Health (Nyapisi, 1988) which showed mild (55µg/l) to moderate (35µg/l) IDD in the Lowlands and Mountains

respectively in children aged 6 to 13 years. However, the median urinary iodine concentration for the whole country (26.3μg/l) is higher than in the recent previous study conducted in Lesotho by Jooste *et al.* (1997). The median urinary iodine concentration in children aged 10 to 14 years was 13μg/l indicating severe iodine deficiency in a baseline cross sectional study at Mohale dam catchment area (Jooste *et al.*, 1997). This shows that although the results of the present study indicate iodine deficiency, there is an improvement in iodine excretion as compared to the recent previous study.

In the whole country, the urinary iodine concentration of 11.3 percent of the children was in the severely deficient range while 82.6 percent was in the moderate range and very few (6.1%) was in the mild range of iodine deficiency. None of the urinary iodine concentrations of the children was in the adequate iodine intake range (iodine excretion concentration >100μg/l). Comparably in a baseline cross sectional study conducted by Jooste *et al.* (1997) at Mohale dam catchment area 60.3 percent of the children aged 10 to 14 years showed urinary iodine concentrations in the severe range of iodine deficiency. A further 25.5 percent was in the moderate range and 6 percent were in the mild range of iodine deficiency. Only 8.2 percent were in the adequate iodine intake range. In view of the two studies, there is an improvement in iodine deficiency where there is a shift to the right in the distribution of urinary iodine levels of the present study with decreased urinary excretion levels in the severely deficient range and increased urinary excretion levels in the moderate range of iodine deficiency.

Although there is an improvement in both the median urinary iodine excretion and iodine distribution showing the severity of IDD in the present study compared to the previous study, there is a concern that a proportion of the children are at risk of developing IDD if no corrective action is taken. Dunn and Van der Haar (1990, p.41) indicated that a substantial percentage of school children with urinary iodine levels lower

than 20μg/l are at significant risk of developing hypothyroidism and mental and physical retardation should the iodine deficiency not be addressed. Therefore 11.3 percent of the children with urinary iodine levels lower than 20μg/l observed in the present study are possibly at risk of developing IDD.

According to the results of the present study and the previous studies, severe to mild iodine deficiency as indicated by urinary iodine excretion persists in Lesotho. This is possibly due to the geographical location of this country. It has been documented that the most severe iodine deficiency occurs in the mountainous areas where the soil has been washed away by snow, rain and glaciers (Dunn & Van der Haar, 1990, p.43; Hetzel, 2000, p.132). Iodine deficiency has also been associated with areas exposed to frequent flooding and winds. Severe iodine deficiency also occurs in lowlands far from the oceans such as the central part of Africa (Delange, 1994). About 75 percent of Lesotho is Mountainous and all the areas have an altitude of more than 1500 metres above sea level (Wolde-Gebriel, 1993). The climate in Lesotho varies with differing topography whereby the mountains have cool summers and cold winters often accompanied by snow, while the lowlands have warmer summers with occasional rain and dry but very cold winters. This geographical situation of Lesotho makes it possible that iodine has been leached from the soil and hence the persisting mild to severe prevalence of IDD in the whole country. This was confirmed in 1993 where analysis of the soil and water collected in different parts of the country indicated no iodine in all the samples (Wolde-Gebriel, 1993) and severe IDD was observed.

Although iodine deficiency is expected in the whole country of Lesotho due to its geographical location, studies have shown that different prevalence of IDD exist within the country. For example, moderate IDD was found in the Mountains while mild IDD was found in the Lowlands (Nyapisi, 1988) and the prevalence of goitre was found to be higher in the

Mountains than in the Lowlands (Wolde-Gebriel, 1993). Similarly the prevalence of low urinary iodine concentration was higher in the Mountains than in the Lowlands in the present study.

The possible reason for the differences in the prevalence of goitre and iodine deficiency within the country (Lesotho) could be that some of the villages in the Mountains are difficult to reach by road. Therefore little access to iodised salt, limited campaigns on IDD awareness and limited supplementation with iodised oil to these areas could be present in the Mountain villages. For example, it was observed in the present study that a higher percentage of children who reported to have never received capsules or received, capsules only once and a higher percentage of non-iodised salt samples were from the Mountains.

The results from urinary iodine excretion in the present study indicate moderate iodine deficiency, which prevail more in the Mountains than in the Lowlands. These results also show an improvement compared to the previous studies but are still of public health concern. Furthermore, the method used for urinary iodine assessment in the present study is considered reliable and valid based on the literature.

4. THE PREVALENCE OF GOITRE

Goitre is usually the most obvious clinical sign of iodine deficiency and is almost invariably the result of inadequate dietary intake (Lamberg, 1993; Delange, 1994). The results from palpation in the present study showing only grade 0 and grade 1 goitres together with the goitre prevalence, which ranged from 2.2 percent to 8.8 percent in the different districts and 3.4 to 7.1 percent in the different ecological zones indicate normal to mild IDD. The goitre prevalence for the whole country is 4.9 percent. This goitre prevalence indicates the absence of IDD according to WHO/UNICEF/ICCIDD (1994) cut-off levels.

The prevalence of goitre has been documented in Lesotho since 1960 where it was found to be 41 percent in school children aged 6 to 13 years (Munoz & Anderson, 1960), 27.8 percent in school children aged 6 to 14 years (Salhis, 1962), 21 percent in school children aged 6 to 13 years (Nyapisi, 1988). Recently the national micronutrient study indicated the total goitre rate of 42.5 percent in children aged 6 to 16 years (Wolde-Gebriel, 1993) and a baseline cross sectional study revealed the prevalence of 17.5 percent in children aged 10 to 14 years (Jooste *et al.*, 1997). The prevalence of goitre in all the above studies was obtained from both grade 1 and grade 2 goitres. Although not comparable due to age differences, the prevalence of goitre in the present study indicates a dramatic decrease from the prevalence of goitre in the previous studies, which indicated mild to severe iodine deficiency. This is possibly due to the use of iodised salt and iodised oil capsules.

The difference in the clinical definitions of goitre in the present study and the previous studies is also a possible reason for the apparent reduction in the prevalence of goitre. For example early previous studies, goitre was classified as follows; grade 0 as no goitre, grade 1a as goitre detectable only by palpation and not visible when the neck is fully extended, grade 1b as palpable goitre and visible only when the neck is fully extended, grade 2 as visible goitre with the neck in normal position and grade 3 as very large goitre than can be recognized at a considerable distance (Munoz & Anderson, 1960; Salhis, 1962; Mpeta, 1987; Nyapisi, 1988). This goitre classification differs with the one used in the recent two previous studies which is the same as the one used in the current study (Wolde-Gebriel, 1993; Jooste *et al.*, 1997)

Several studies have shown that goitrous children are nutritionally deprived (Pardede *et al.*, 1998) and perform worse in exams (Benade *et al.*, 1997) than the non-goitrous children. A great concern is in the fact that the effects of iodine deficiency occur as a spectrum of abnormalities ranging from normal through sub-clinical conditions to overt neurological

and physical abnormalities and cretinism. This means that children showing endemic goitre as observed in the present study may already be adversely affected, resulting in educational and socio-economic underdevelopment. It would therefore have been of benefit to include anthropometric measurements and evaluate the exam marks of the children in the present study. However these measures are recommended for future studies to give an idea of the effect of iodine deficiency in Lesotho.

Similar to urinary iodine excretion, the prevalence of endemic goitre varies from region to region in Lesotho and also among some sub-populations in the same region. For example the prevalence of goitre was found to be higher in the Mountains than in the Lowlands in the present study. Similar results have also been shown in the previous studies on iodine deficiency conducted in Lesotho since 1960 (Munoz & Anderson, 1960; Nyapisi, 1988; Wolde-Gebriel, 1993). This is possibly due to limited availability of iodised salt and inadequate supplementation with iodised oil.

The prevalence of goitre increases with age reaching a maximum after the first decade (WHO, 1993; Delange, 1994). The results from the present study also indicate that the prevalence of goitre increases with age where it was 3.0 percent for the children aged 8 years and increased to 6.4 percent in children aged 12 years. The prevalence of goitre also increased with age in both sexes up to the age of 12 to 14 years in children aged 5 to 15 years in a baseline study conducted at Mohale Dam catchment area in Lesotho (Jooste *et al.*, 1997). Similar results were obtained in Italy (Tiberina Valley) where a large majority of 11 to 14 year old children showed a subtle enlargement of the thyroid gland (Aghini-Lombardi *et al.*, 1997). They also suggested in their study that the exposure to mild to moderate iodine deficiency in childhood causes subtle enlargement of the thyroid gland in the juvenile population that may persists after correction of iodine deficiency. This is also possibly the

reason for the increased prevalence of goitre in older children in the present study.

In reviewing the prevalence data on goitre throughout the world, females from adolescence onwards generally have a higher prevalence of goitre than males, perhaps due to differences in the metabolism of iodine during growth (WHO, 1993). The adjusted goitre prevalence of 5.4 percent in girls and 4.5 percent in males in the present study confirms the results from many studies, which indicate that girls have a higher prevalence of goitre than boys. Similarly the prevalence of goitre was 41.8 percent in females and 40 percent in males in school children aged 6 to 13 years (Munoz & Anderson, 1960), 41.6 percent in females and 34.4 percent in males in school children aged 6 to 16 years (Wolde-Gebriel, 1993) and 20 percent in females and 12.4 percent in males in school children aged 5 to 15 years (Jooste *et al.*, 1997). All the above studies conducted in Lesotho clearly show that the prevalence of goitre is higher in females than males, which is in accordance with the findings of other studies.

It has been stated that dietary iodine deficiency is usually the primary cause of endemic goitre but other factors such as goitrogens, drug side effects or other trace element deficiencies may also induce the development of goitre (Authur *et al.*, 1993). These factors, more importantly goitrogens as a possible contributing factor to the aetiology of endemic goitre in Lesotho were however not investigated in this study. It is possible that they played some minor role in causing or aggravating the goitres, but in view of poor iodine status reflected by low urinary iodine excretion, it is evident that an inadequate iodine intake was the major cause of the goitres in the present study.

Palpation used as a clinical assessment in the present study is reliable when thyroids are grossly enlarged and it is inaccurate in distinguishing mild thyroid enlargement from normal (Dunn, 1996; Vitti *et al.*, 1994). Although great efforts were taken to eliminate both intra and inter

observer variations during palpation in the present study, the reliability of this method is still of concern since the result show only grade 0 and grade 1 goitres. It is stated that in the mild endemicity and generally whenever goitres are small that is, grade 1 or bordering on either grade 0 or grade 2, inter observer variation can be as high as 40 percent (WHO/UNICEF/ICCIDD, 1997). A great concern is the fact that the inter observer variation in the diagnosis of grade 0 and grade 1 goitre could result in the overlapping of mental and physical abnormalities between goitrous and non goitrous children living in the same environment (Tonglet, 1994). It could also result in severe endemic goitre, from thyroid failure occurring during the fetal or postnatal period, which is during the critical period of brain development (Delange, 1994).

It is possible, however, that if another method was used to determine the size of the thyroid, different results would have been obtained in the present study. The prevalence of IDD was influenced by the method used to identify goitre in Germany (Pardede *et al.*, 1998). For example in the village of Priggodani, all children were identified with goitre using ultrasonography whereas in Karangsari, no signs of thyroid enlargement were found. In contrast when the same children were assessed by palpation, the prevalence of goitre in two villages was nearly the same. Similarly the total goitre rate determined by ultrasonography in Indonesia was nearly 50 percent higher than determined by palpation (Pardede *et al.*, 1998). In the area of Eastern Tuscany in Italy, goitre prevalence at ultrasound was also higher than found by palpation, whereas in the control area goitre prevalence was lower at ultrasound than observed through palpation (Aghini-Lombardi *et al.*, 1997). It is therefore possible that if ultrasonography, was used in the present study, the thyroid sizes determined would be different.

Determination of thyroid size by ultrasonography has now become standardized and is to be preferred when this technology is available because it is an objective measure (Hetzel, 2000, p.164). However in the

absence of ultrasonography, clinical examination of thyroid size by palpation and classification into goitre grade 0, 1, and 2 provides an acceptable and simple alternative. Great efforts were taken to ensure validity and reliability of palpation in the present study and it was also used in combination with urinary iodine measurement, which is a reliable indicator. Therefore palpation is taken as an important variable, which indicates the presence of IDD in Lesotho. It has been stated that palpation is most useful, as an initial signal that IDD may be present and as an indicator that more refined assessment is needed (Hetzel, 2000, p.164)

The results from the palpation in the present study indicated the absence of IDD according to WHO/UNICEF/ICCIDD (1994). The prevalence of goitre, which increased with age, was also found to be higher in females than males and higher in the Mountains than in the Lowlands. Compared to previous studies the prevalence of goitre has dramatically decreased.

5. IODISED OIL SUPPLEMENTATION

Oral administration is now regarded as the optimal mode for delivery of iodised oil (Hetzel, 2000, p.164). Some countries have refused to adopt short term measures such as iodised oil, while working their way though the complex changes in the salt trade that are necessary to deliver iodised salt successfully (Dunn, 1996). This delay however exposes the population to needless continuation of iodine deficiency and its consequences particularly those of mental retardation. Usually a country should choose iodised salt as its long-term solution and decide whether short-term intervention such as iodised oil is also necessary for prompt relief.

According to WHO/UNICEF/ICCIDD (1994), iodised oil supplementation coverage of 55.1 percent as found in the present study is not adequate. This is possibly due to the fact that some children either got the first

(1995-1996) or the second (1997-1998) supplementation. Most of these children were living in the Mountains where some schools are not accessible by road. Also most of the children aged 8 and 9 years reported not to have received capsules in 1995 to 1996 and this is because they were not at primary school during those years.

Iodised oil programs have conclusively been shown to be effective in preventing and treating endemic goitre and preventing endemic cretinism and the alterations of psychomotor intellectual development, which are frequently encountered in non-cretinious individuals (Delange, 1996). For example short-term success in reducing goitre rates was achieved in England in efficacy studies with iodised oil (Tonglet *et al.*, 1992). Although supplementation coverage was not adequate, it is likely that iodised oil supplementation could have contributed to a decrease in the prevalence of goitre and probably a slight increase in urinary iodine excretion that were demonstrated in the present study.

The dose of iodine and duration of exposure are very important in iodine prophylaxis with iodised oil. For example, a multicentre study in children (Algeria, India, Peru) revealed that 1ml oral oil, which contains 480mg of iodine provides coverage for 1 year and half that dose gave satisfactory coverage for 6 months (Benmiloud *et al.*, 1994). A longer duration of exposure was observed when iodised oil Lipiodol, a popyseed oil in which 1ml contains 480mg iodine lasted 2 years in Zaire (Tonglet *et al.*, 1992). Although it was suggested in this study that a dose of 500 to 1000mg of iodine should be given every second or third year, it was however found that even doses of around 100mg or less seem to be effective for at least a year (Tonglet *et al.*, 1992).

All people aged 2 to 49 years in Lesotho were given capsules of which 1ml (1 capsule) contains 200mg of iodine. The capsules were distributed in 1995 to 1996 and in 1997 to 1998 while the present study was conducted in 1999. There was therefore duration between the last oil

capsule distribution to the time of study of about 2 years (for children who received capsules in 1997) and about 1 year (for children who received capsules in 1998). Based on the above studies, capsules containing 200mg of iodine given to children in Lesotho were possibly still effective during the present study in children who received capsules only in 1998. It was also possible that due to the long duration between supplementation and the time of the present study, iodised oil supplementation did not significantly affect the urinary iodine concentration, which reflects the current IDD situation. However it has been stated that at least 6 to 12 months is required to show regression of goitre with iodised oil treatment (Tonglet *et al.*, 1992). It is therefore possible that iodised oil supplementation had an effect on the goitre status in the present study.

More impressive results could have been expected in the present study but several factors could have affected the effectiveness of oral iodised oil as was also shown by Furnee (1997). For example the presence of intestinal parasite reduces duration, boys and girls between age 8 and 10 have different duration of effectiveness, fat children retain more iodine from an oral dose of iodised oil than children with little fat, goitrous subjects retain more iodine than non- goitrous subject and goitrogen (e.g cassava and cabbage) consumption reduces the duration and seasonality influence the duration of this prophylaxis measure. In Lesotho, the high consumption rate of cabbage, the presence of intestinal parasites in children and the high prevalence of malnutrition have been documented (Wolde-Gebriel, 1993). It is therefore possible that some of these factors affected the effectiveness of oral iodised oil capsules in Lesotho. In addition, literature findings indicate that iodine supply is higher with non vegetarian diet than with vegetarian diet (Remer *et al.*, 1999) and in Lesotho due to poverty, most people depend mainly on vegetables, which put them at risk of developing iodine deficiency disorders.

A dramatic decrease in the prevalence of goitre and an increase in urinary iodine excretion in the present study compared to previous studies is probably due to the fact that iodised oil supplementation was coupled with the use of iodised salt. Similarly it was found that the prevalence of goitre declined and median urinary iodine increased within one year in a group given iodised oil capsules containing 400mg and purchasing iodised salt at different iodine content in China (Zhao, 1999).

Although iodised oil supplementation coverage was not adequate in the present study, it is likely that it has contributed to a decrease in the prevalence of goitre in Lesotho. There are, however several factors, which have possibly affected the prophylaxis of iodised oil in Lesotho and these needs to be investigated in the future studies.

6. SALT IODISATION

Universal salt iodisation is the recommended long-term sustainable intervention for preventing and correcting iodine deficiency (WHO, 1996). A major achievement is the spectacular reduction of IDD in countries that have implemented universal salt iodisation. The 1994 draft legislation on universal salt iodisation was made law in 1999 and promulgated in 2000, however, this present study indicates that 5.2 percent of households use non iodised salt and 94.8 percent use iodised salt. There is an increase in the use of iodised salt as compared to previous studies. For example a collaborative study undertaken jointly between the Ministry of Health and the National University of Lesotho (1990) revealed that 24 percent of households in Lesotho use non-iodised salt. A more recent quantitative study indicated that 15.3 percent of households in Lesotho use non-iodised salt (Sebotsa, 1998). All these studies demonstrate an upward trend in the use of iodised salt.

These impressing results on iodised salt consumption are mainly due to awareness campaigns initiated in 1994. Public awareness was done

through local radios, local gatherings (Pitsos), newspapers, posters and pamphlets on the use of iodised salt. The traders' workshops where the traders were educated on IDD and the importance of iodised salt were also of benefit. More importantly these impressive results are also attributed to the introduction of the legislation in South Africa in 1995, which changed the iodine content of salt from the range of 10 to 20ppm to the range of 40 to 60ppm. Since Lesotho import most of its salt from South Africa this legislation contributed to an increase in the availability of iodised salt in Lesotho.

The use of non-iodised salt in the present study was observed mainly in the Mountains. This is possibly due to the fact that awareness campaigns on IDD and the use of iodised salt were not adequately done due to remoteness of some areas in the Mountains. It is also possible that most people in the Mountains depend on farming therefore non iodised salt, which is coarse salt packed in bags of 50kg is purchased for the purpose of animal consumption but since it is cheap it is used for human consumption as well. Similarly non- iodised salt was used mostly in the Mountains in a recent study conducted in Lesotho by Sebotsa (1998) and it was found in this study that non-iodised salt was used by households because it was cheap (15%) and was mainly used by farmers (34.1%) for both animal and human consumption.

The effectiveness of iodised salt prophylaxis to correct iodine deficiency and reduce goitre prevalence is reported in several studies. For example in Car Nicobar where IDD pose a mild to moderate public health problem, the supply of iodised salt and its iodine content was found to be adequate, that is 82.5 percent had iodine of 15ppm (Mallik *et al.*, 1998). The prevalence of goitre was also shown to have drastically decreased and the median urinary iodine levels were equal or above the cut-off point of 100μg/l in all countries in a seven-country study in Africa (Botswana, Cameroon, Democratic Republic of Congo, Kenya, Nigeria, Tanzania, Zambia and Zimbabwe) after the introduction of iodised salt

(WHO/UNICEF/ICCIDD, 1996). Similarly salt iodised at a concentration of 40ppm to 60ppm was found to be effective in eradicating mild iodine deficiency within a period of 4 months in primary school children in the Windsorton district in South Africa (l'Ons *et al.*, 2000). Similar to the above studies, the awareness campaigns on the use of iodised salt, which started effectively in 1994 and the introduction of the 1995 legislation in South Africa, which changed the iodine content of salt have possibly resulted in a remarkable decrease in the prevalence of goitre and an increase in the urinary iodine excretion in the present study.

Although there was an improvement in the urinary iodine excretion in the present study compared to the previous studies, the urinary iodine status indicates moderate IDD deficiency. This is not expected with the use of iodised salt by most of the children (94.8%) as indicated by the results in the present study. It is possibly due to the fact that rapid test method, which is described as qualitative, was used in this study, therefore the exact iodine content in the salt samples, were not obtained. For example, it has been stated that the intensity of the blue colour, which develops during salt testing indicates the salt iodine level with an accuracy of (+/-10ppm) (WHO/UNICEF/ICCIDD, 1994). Also a more recent quantitative study (using titration method) showed that 71 percent (<90%) of households in Lesotho use effectively iodised salt (Sebotsa, 1998). It is therefore likely that the results obtained from salt analysis in the present study would be higher than would have been obtained by titration method.

Besides the inaccuracy of the rapid test method, another possible reason for the high iodine salt content with moderate urinary iodine status obtained in the present study is due to the fact that children were made aware that the salt samples were going to be tested. Since this was not done for the first time in schools, they knew salt samples were going to be analysed for iodine content, therefore they probably purchased iodised salt the same day or the previous day of the study. It is therefore likely that some of the salt samples tested were from the retail level not the

household level as was the objective of the study. Several factors such as exposure of salt to moisture and heat, which normally happens at household level affect the iodine content of salt (Chauhan *et al.*, 1992) therefore iodine content of salt at retail level is expected to be higher than iodine content of salt at household level.

The prevalence of goitre has dramatically decreased in the present study compared to the previous studies unlike a slight increase in urinary iodine excretion. One of the reasons for the lack of change in the goitre grades of children in the Langkloof area in South Africa was insufficient time of exposure to mandatory iodisation (Jooste *et al.*, 2000). Contrarily, the children in Lesotho had been exposed for a longer time to the use of iodised salt. The people had been educated on the use of iodised salt since 1994 and as a result goitre prevalence is decreased. The role of goitrogens which also contribute to iodine deficiency, was also taken into account during awareness campaigns where people were advised to increase cooking time of goitrogenic substances especially cabbage which is used mostly by the households.

The use of iodised salt coupled with iodised oil has possibly brought great improvement in the prevalence of goitre and an increase urinary iodine excretion. The results from this study are consistent with many studies which demonstrate a rapid increase in urinary iodine excretion and a dramatic decrease in goitre prevalence in children born and living in iodine deficient areas after the implementation of iodised salt and oral or parental iodised oil administration (Aghini-Lombardi *et al.*, 1993; Benmiloud *et al.*, 1994). Similar results were observed in China where the prevalence of goitre declined from 18 percent to less than 5 percent in 12 months and the median urinary iodine increased from 94µg/l to 200µg/l during 6 months of follow-up in a group provided with iodised salt with an iodine content of 25ppm and in a group given iodised oil capsules containing 400mg and purchasing iodised salt at different iodine content (Zhao, 1999).

In the present study the children were not iodine replete while the prevalence of goitre indicated absence of IDD. The above studies however show a better concordance in Urinary iodine excretion and the prevalence of goitre. The rapid decrease in the prevalence of goitre in the present study can be attributed to the palpation method used, which is less reliable than ultrasonography. Similarly the urinary iodine excretion, which is not normalised as in the above studies is possibly due to consumption of less adequately iodised salt at household level as indicated by the results of the present study.

Dunn (1996) has indicated that a common error is the failure to include domestic animals in the salt iodisation scheme since animals need iodine too and if cheap non-iodised salt is available for them, it will often, be used by humans as well, thus subverting the effectiveness of iodisation program. However the legislation in Lesotho includes iodisation of salt for animal consumption and hopefully iodine deficiency disorders will be eradicated after it has been enforced. The legislation in South Africa where Lesotho gets most of its salt does not include iodisation of salt meant for animal consumption. To ensure that all salt imported to Lesotho is iodised, copies of the Lesotho legislation have been given and explained to some salt-plant owners near the country. Traders' workshops have also been initiated where traders are informed of the Legislation and are provided with salt test kits to make sure that all salt exported to Lesotho is iodised. However, until the animal salt in South Africa is iodised there will possibly be some non-iodised salt imported to Lesotho, therefore a strong monitoring program is needed in Lesotho especially at entry points.

It is expected that after the introduction and enforcement of the universal salt iodisation legislation in Lesotho, there will be an increase in the use of iodised salt and consequently a reduction in iodine deficiency as has been indicated in several studies. For example, studies in Tanzania indicated

that after the legislation for iodisation of salt was enacted in 1993, the proportion of households consuming iodised salt in the highly endemic areas steadily rose from 0 percent to 90 percent in some areas and a reduction in iodine deficiency was observed (Hetzel, 2000, p.629). Similarly in Kenya, the prevalence of goitre in three districts declined rapidly and there was an increase in urinary iodine excretion after the introduction of the legislation for salt iodisation (Gitau, 1995).

Endemic goitre, however, persists in some countries with mandatory salt iodisation, for example in Hungary and Yogoslavia, as well as in countries with voluntary iodisation such as Germany, Italy and Spain (Jooste *et al.*, 1997). This therefore indicates that neither voluntary nor mandatory iodisation of table salt will automatically guarantee success in eradicating iodine deficiency and endemic goitre. The key issue to ensure success of the public health measure lies in the effective implementation and subsequent monitoring of the iodisation program and its effects. There are potentially a number of factors, which could influence the impact of mandatory iodisation in Lesotho, varying from the effectiveness of iodisation to the efficient distribution of iodised salt and eventual iodine intake. An effective monitoring program at all levels is therefore important in Lesotho.

It appears that some people in some countries now have iodine intakes that are necessarily high and that may occasionally be associated with IIH (WHO, 1996). IIH which is one of the Iodine deficiency disorders has not been investigated in all the studies in Lesotho but it has been concluded that IIH associated with iodine prophylaxis programs in developing countries is probably an important and underestimated problem that is difficult to recognize clinically and may be life threatening (Bourdoux *et al.*, 1996; Communique, 1995). A higher incidence of IIH in older groups has been reported and about 30 percent of the population in Africa is believed to be at risk (WHO/UNICEF/ICCIDD, 1996). There is a possibility,

therefore, that a degree of IIH exists in Lesotho and it needs to be investigated.

The result in the present study indicates that the use of iodised salt has increased as compared to previous studies. Attributed to the awareness campaigns and the introduction of 1995 salt iodisation legislation in South Africa, iodised salt has possibly resulted in a decrease in the prevalence of goitre and an increase in urinary iodine. A major limitation in this study was the use of spot tests instead of the standard titration method, a more precise and quantitative method in the analysis of iodine in salt. It would have been of benefit for this study to find out what percentage of households in Lesotho use adequately iodised salt. Spot tests used in the present study provide valuable information for the monitoring of salt iodine quality as well as creating awareness and demand within the community to consume only iodised salt (PAMM/MI/ICCIDD, 1995). For this reason, the results obtained in this study were used only to indicate the presence of iodine in salt.

7. SUMMARY

A dramatic decrease in the prevalence of goitre and an increase in the urinary iodine excretion compared to the previous studies were observed. Although there is improvement in iodine deficiency as compared to the previous IDD studies, the results of the present study still indicate that iodine deficiency is a public health problem in Lesotho. This shows that Lesotho has not reached the goal of virtual elimination of IDD as a public health problem by the year 2000, which was accepted by the United Nations in 1990. Coverage on iodised oil supplementation was found not to be adequate, however a high percentage of the children in Lesotho received the capsules. An increase in the use of iodised salt by the households was also observed as compared to previous studies. Both iodised oil supplementation and iodised salt have possibly contributed to a

decrease in the prevalence of goitre and an increase in urinary iodine concentration.

The results of the present study showed that the prevalence of goitre and low urinary iodine concentration was higher in the Mountains than in the Lowlands. This is probably due to lack of access to iodised salt and inadequate distribution of iodised oil capsules. The use of iodised salt, which has also increased was attributed to awareness campaigns on IDD and the importance of iodised salt, which were more effective starting from 1994 and the 1995 salt iodisation legislation in South Africa. Non-iodised salt was found mainly in the Mountains where it is normally used for both animal and human consumption because it is cheaper than iodised salt.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

This chapter gives a brief general discussion of the findings of the present study, followed by recommendations obtained from the findings. The estimates in the findings should be considered as representative of the situation in Lesotho because of the high response rates of the school children achieved in this study and a high school attendance rates reported by the Head Teachers. The methods used were also valid and reliable. The current IDD status is evaluated to make the best possible recommendations to the benefit of the country.

1. CONCLUSIONS

Urinary iodine analysis is the most common biochemical method used for assessing the iodine status of populations and therefore plays an important role in public health surveillance in may countries (May *et al.*, 1997). Urinary iodine excretion was therefore taken as an important variable in this study to indicate the current IDD situation in Lesotho. The median urinary iodine concentration, which is 26.3µg/l for the whole country indicate moderate iodine deficiency and these reflect the current iodine deficiency situation in Lesotho. The results on urinary iodine excretion show an improvement compared to previous studies, which indicated mild to severe IDD. Based on WHO/UNICEF/ICCIDD (1994) criteria, iodine deficiency is, however, still a public health problem since more than 20 percent and more than 50 percent of school children had urinary iodine concentrations below 50µg/l and 100µg/l respectively.

The results from urinary iodine excretion convincingly demonstrated the existence of iodine deficiency of moderate severity and public health problem in need of correction. As all the children had iodine nutrition less

than the cut-off level of 100µg/l, it is clear that moderate iodine deficiency indeed exists in this population at a level, which could affect their mental health. Based on the results of the present study the goal of virtual elimination of IDD as a public health problem by the year 2000, which was accepted by the United Nations Systems in 1990 has not been reached in Lesotho.

The low urinary iodine excretion measured in these children confirmed that an inadequate iodine intake caused their goitre. Despite the low urinary iodine observed in this study, thyroid sizes showed only grade 0 and grade 1. This is perhaps due to the fact that urinary iodine excretion reflects the current situation of iodine supply while goitre volume indicates the longer term of iodine status (Hetzel, 1993). Therefore the prevalence of IDD determined by the two indicators does not necessarily need to be consistent. However a large variation between the two variables in the present study, brings the conclusion that, there was invalidity in the palpation method.

On the basis of total goitre rate, suggested by WHO/UNICEF/ICCIDD (1994), and measured by palpation in the present study, the goitre prevalence of 4.9 percent indicates the absence of iodine deficiency in Lesotho. Although great efforts were taken to eliminate both intra and inter observer variation during palpation the conclusions and recommendations in the present study will only be based on the urinary iodine excretion results. This is mainly due to the invalidity of the palpation method used to assess thyroid size especially when thyroids are not too enlarged as observed in the present study.

The operational supplementation coverage of 55.1 percent was found not to be adequate based on WHO/UNICEF/ICCIDD (1994) criteria, that is, at least 95 percent of primary school children should have received iodised oil both in 1995/1996 and in 1997/1998. A higher percentage of children in the Mountains received capsules once, that is, either in 1995/96 or in

1997/98 and also a higher percentage of children never received supplementation in this zone. Iodine supplementation is therefore still needed in these areas. Even though the iodised oil supplementation coverage was not adequate, iodised oil supplementation was found in the present study to have most likely had an effect to a decrease in the prevalence of IDD.

Even though the results on urinary iodine excretion show mild to moderate iodine deficiency, a large proportion of the school children (94.8) seem to consume iodised salt. This study however does not indicate how many children consume adequately iodised salt. This is because the rapid test method used is qualitative. The use of iodised salt in Lesotho has also possibly contributed to a decrease in IDD prevalence. However a proportion of households still use non-iodised salt, which is salt meant for animal consumption and most of them live in the Mountains. Awareness campaigns seem to be effective in reducing the iodine deficiency in Lesotho. In contrast to the South African legislation, the legislation in Lesotho considers iodisation of animal salt. Therefore effective control program especially at points of entry and traders workshops will be of great importance to ensure that iodised salt enters the country as stipulated in the legislation.

2. RECOMMENDATIONS

2.1 PREVENTION OF IDD IN LESOTHO

The primary reason for the iodine deficiency of these children is most likely a poor iodine content of the soil and water used for food production in Lesotho accompanied by limited other dietary sources of iodine such as sea food (Wolde-Gebriel, 1993). It has been stated that one of the most significant and common sources of dietary iodine is iodised salt and with the increase in consumption rate of iodised salt there is hope that the iodine status will change. The micronutrient task force should therefore

work together with the government of Lesotho to ensure proper enforcement of the universal salt iodisation legislation.

According to the literature IDD can be prevented by the use of iodised salt and where iodised salt will not reach the population the use of iodised oil is recommended. Since it might take some time to have all salt meant for animal consumption iodised, iodised oil supplementation should be continued as a short term intervention especially in the Mountains and in schools, which never received iodised oil supplementation.

Education at all levels is a key to any effective program and failure to include it regularly dooms success (Hetzel, 1993). Awareness campaigns on the use of iodised salt must also be continued and strengthened so that even those people in remote areas receive the messages.

2.2 MONITORING

It is internationally accepted that salt iodisation is the most sustainable and potentially the most effective way of eliminating iodine deficiency in countries. It has also been stated that regular monitoring of salt iodine content at various points need to be undertaken to ensure that sufficient iodine is available at the point of consumption. Salt must be monitored regularly at production level, entry points, retail level and household level. This will ensure distribution of adequately iodised salt to the entire population. According to WHO (1993), a national monitoring program should include the following requirements for monitoring iodine status and adequacy of iodine levels in salt:

- Establishing an IDD committee of qualified individuals who are responsible for program monitoring and evaluation
- Ensuring regular quality control of iodine concentration in salt at the point of production by using titration methods or, in the case of imported salt, at the point of entry by using reliable test kits.

Consignments with suspect iodine levels should be checked by titration.

- Setting up independent laboratories capable of carrying out salt iodine titration and urine iodine analysis to ensure external quality control.
- Designating sentinel sites to carry out the following activities:
    1. Monitoring periodically salt iodine levels in retail shops and households using reliable kits.
    2. Conducting occasional goitre prevalence surveys.
    3. Measuring regularly urinary iodine.
- Adjusting salt iodine levels based on monitoring results especially of iodine in urine.
- Alerting health workers to possible occurrence of hyperthyroidism, and ensuring access to appropriate treatment when necessary.
- Establishing a health notification system for cases of hyperthyroidism at selected hospitals in areas of former severe/moderate iodine deficiency.

Based on the situation in Lesotho and considering the above requirements, the following recommendations are made to strengthen the Lesotho's monitoring program.

- A regular monitoring program, which will support, expand and strengthen the salt iodisation program, needs to be initiated in Lesotho. This can be done by motivation of the existing members of the Micronutrient task force, which include personnel from various relevant Ministries. These members need both internal and external training on all aspects of quality control and law enforcement. After being well equipped the members will train together with other members of the taskforce where necessary personnel involved with day to day activities of ensuring adequately iodised salt availability in all the districts in their respective Ministries.

- The National University of Lesotho laboratory currently being used for urinary iodine analysis should also be used for titration so that salt samples obtained from household, retail and entry points will be regularly analysed for iodine. Since this has never been done in Lesotho, training will be required. This laboratory should also participate in quality control exercises and exchange samples regularly with internationally reputable laboratories.
- Coarse salt (usually packed in bags of more than 20kg capacity and non-iodised) is normally purchased for animal purposes and used for human consumption as well. To ensure than only iodised coarse salt is available in the country, traders should be convinced to purchase iodised coarse salt. The increasing demand of iodised coarse salt from salt producers will urge them to iodise salt to the Lesotho's specifications.
- In their regular training schedule, the Ministry of Health and Ministry of Agriculture should include training on the prevention and control of IDD to the public health nurses, community health workers and Agriculture extension workers. Additionally, with the help of the Ministry of Education, a module on IDD and its prevention and control should also be included at the National Health Training College and Lesotho Agricultural College.

2.3 OTHER TYPES OF STUDIES

A follow up study after the legislation has been enforced is recommended to evaluate its effectiveness. Many national studies in Lesotho have concentrated on IDD in school children. Thus supplementation of iodised oil capsules gave preference to this group. Observations by health and nutrition officials and some previous studies indicated IDD in women of childbearing age. Therefore a recent national study on IDD in this group will definitely cast more light on the current IDD situation in Lesotho. The

use of ultrasonography though expensive must be considered to provide a more precise measurement of thyroid volume especially in low goitre rates. Also during monitoring the use of titration method for salt testing should be considered instead of rapid test kits.

Studies have shown that iodine deficiency occur as a spectrum of abnormalities ranging from normal through sub-clinical conditions to overt neurological and physical abnormalities and cretinism (Hetzel, 1993). Anthropometric measurements and evaluation of exam marks are important, easy and non-expensive variables, which show the effects of iodine deficiency and are therefore to be included in future studies. It has been stated that some people in some countries now have iodine intakes that are unnecessarily high and that may occasionally be associated with IIH (WHO, 1996). The prevalence of IIH should also be investigated in Lesotho especially after the enforcement of the universal salt iodisation legislation.

3. THE FINAL WORD

Mild to moderate iodine deficiency, which shows an improvement as compared to previous studies exists in Lesotho and it is still a public health problem according to WHO/UNICRF/ICCIDD (1994). Oral iodine supplementation was found to be effective in controlling IDD in some regions in Lesotho and needs to be continued in the Mountains and in schools, which never received the capsules. The increased use of iodised salt has also contributed to the decrease in IDD prevalence. Awareness campaigns were found to be beneficial in increasing the use of iodised salt by households therefore need to be continued more efficiently so that even the people in the Mountains receive the massages.

The information from this study will be used as a basis of the IDD situation in Lesotho before 2000 and as a tool, which highlights the extent of the IDD problem. It highlights the need for future studies on IDD and the

possible factors contributing to IDD in Lesotho and stimulates action including procurement of iodised oil capsules while dealing with the enforcement of the legislation. Furthermore it will be used as a baseline for long-term monitoring of the IDD situation in Lesotho.

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APPENDICES

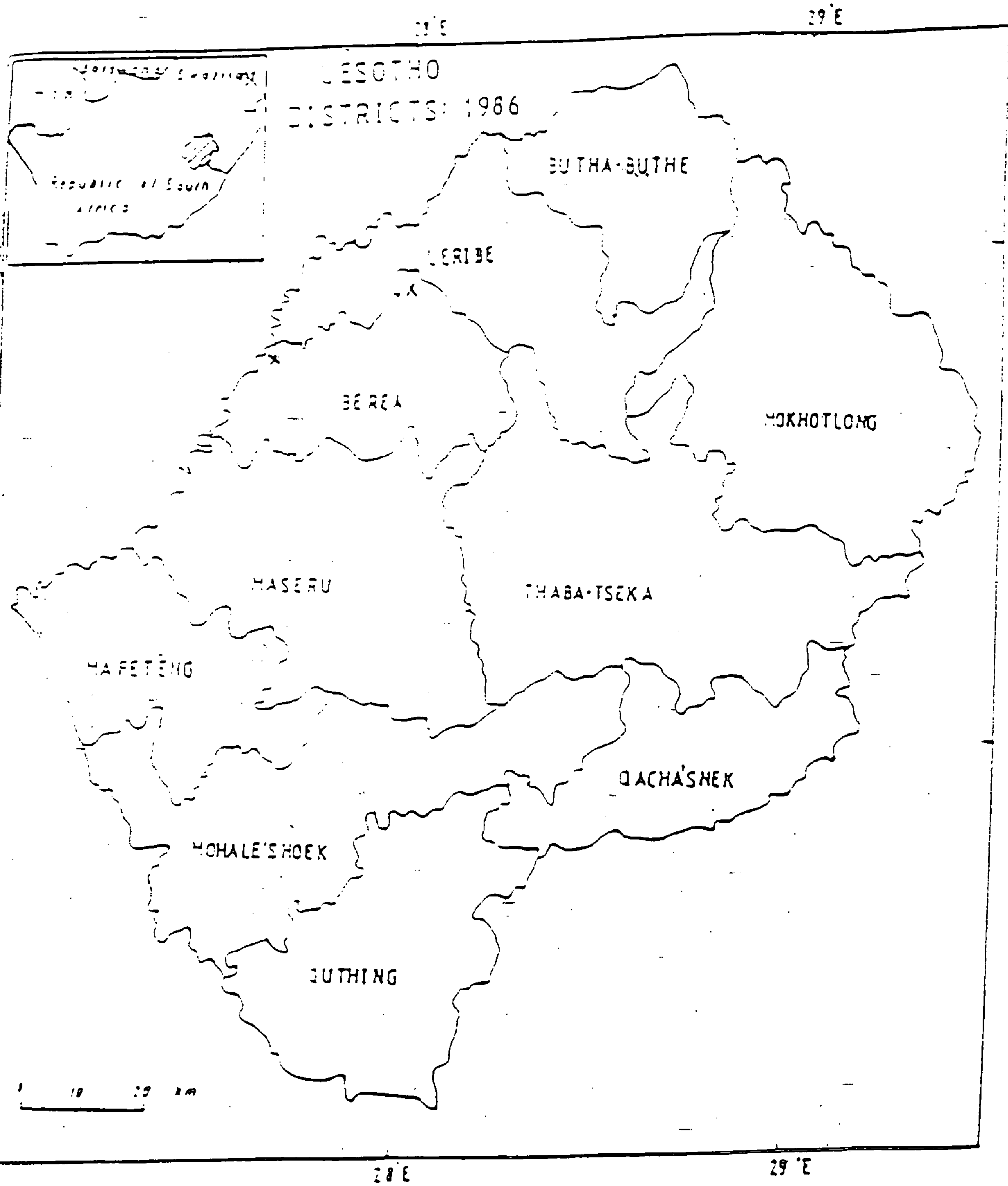
APPENDIX 1: A MAP PRESENTING THE GLOBAL GOITRE PREVALENCE INFORMATION

PREVALENCE OF IODINE DEFICIENCY DISORDERS

GLOBAL DISTRIBUTION

Source: WHO, 1993

APPENDIX 2: THE TEN ADMINISTRATIVE DISTRICTS OF LESOTHO



NDIX 3: THE LESOTHO LEGISLATION ON UNIVERSAL SALT
ATION

LESOTHO
Government Gazette
Extraordinary

Vol. XLIV Wednesday – 10th March, 1999 No. 16

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No. Misc Plan 1/99 Phomolong Maseru South Urban Area)
Notice, 1999

Published by the Authority of His Majesty the King
Price: 90 Lisente

LEGAL NOTICE NO. 13 of 1999
Lesotho Iodization Regulations, 1999

Pursuant to section 71 of the Public Health Order 1970[1], I,

VOVA BULANE

Minister of Health, make the following Regulations:-

Citation and commencement

1. These Regulations may be cited as Lesotho Salt Iodization Regulations, 1999, and shall come into operation on the date of publication in the Gazette.

nterpretation

2. In these Regulations, unless the context requires otherwise,
"food grade salt" means salt containing not less than 97% crystalline sodium chloride on a dry matter basis, including table salt and coarse salt;
"impermeable packaging material" means material which may consist of one or more of the following substances: low density polyethylene, high polyethylene, woven polypropylene or similar materials, and includes polycoated cardboard;
"iodated salt" means food grade salt or other salt intended for human and animal consumption to which between 40 and 60 ppm (mg/kg) iodine in the form of potassium iodate has been added;
"low sodium salt" means salt containing less than 67% sodium chloride;
"the Order" means the Public Health Order, 1970, Order No. 12 of 1970, and any expression to which a meaning has been assigned in the Order shall bear that meaning;
"table salt" means salt that contains no more than 4% moisture and 40-60 ppm (mg/kg) fluoride and not less than 98.4% sodium chloride in its water free state.

equirements

A manufacturer shall ensure that:-

(a) food grade salt or other salt intended for human or animal consumption which is imported into Lesotho shall contain between 40 and 60 ppm (mg/kg) iodine and labeled "iodated salt";
(b) iodated salt is to be packed in sealed impermeable packaging material with a lining of high density polypropylene;
(c) the date of iodation is to be indicated on the label of the product together with other information such as lot or batch number, manufacture date, expiration date of the salt and net weight thereto.

ndom check tests

(1) Health Inspectors shall conduct and administer random check tests at retail

level to monitor salt iodine quality and levels.

2) Customs and Excise officials shall conduct random check tests at all ports of entry into Lesotho to monitor salt iodine levels on all imported salt.

Offences

5. (1) No person shall –

(a) import into Lesotho; or
(b) sell.

food grade or other salt intended for human or animal consumption unless iodine has been added thereto.

(2) A person who contravenes the provisions of sub-regulation (1) commits an offence and is liable on conviction to a fine not exceeding one thousand maloti or imprisonment for a period not exceeding one year, or both fine and imprisonment.

(3) In addition to a fine or imprisonment imposed under sub-regulation (2), the Health Inspectors shall confiscate such salt.

Exemptions

. These Regulations shall not apply to food grade salt or other salt intended for-

(a) use in the manufacture of compound food stuffs which is packed in bags of 20 kg or more and labeled "non-iodated salt"; or
(b) experimenting purposes

DATED:

V. Bulane
Minister of Health

NOTE

Order No. 12 of 1970 -

APPENDIX 4: THE LEGISLATION ON SALT IODISATION IN SOUTH AFRICA

No. R. 996] [7 July 1995

REGULATIONS RELATING TO SALT

The Minister of Health has, in terms of section 15 (1) of the Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act No. 54 of 1972), made the regulations in the Schedule.

SCHEDULE

Definitions

1. In these regulations "the Act" means the Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act No. 54 of 1972), and any expression to which a meaning has been assigned in the Act shall bear that meaning and, unless the context indicates otherwise—

"**food grade salt**" means salt containing not less than 97% crystalline sodium chloride on a dry matter basis, including table salt;

"**impermeable packaging material**" means material which may consist of one or more of the following substances: Low density polyethylene, high density polyethylene, woven polypropylene or similar materials, and includes polycoated cardboard;

"**iodated salt**" means food grade salt or other salt intended for use in or on foodstuffs to which between 40 and 60 ppm (mg/kg) iodine in the form of potassium iodate has been added;

"**low sodium salt**" means salt containing less than 67% sodiumchloride; and

"**table salt**" means salt that contains no more than 4% moisture and 50 ppm (mg/kg) fluoride and not less than 98,4% crystalline sodium chloride in its water-free state.

Requirements

2. (1) No person shall sell food grade salt or other salt intended for use in or on foodstuffs unless iodine has been added thereto.

(2) Food grade salt or other salt intended for use in or on foodstuffs which is imported shall contain between 40 and 60 ppm (mg/kg) iodine on entering the Republic of South Africa.

(3) Food grade salt or other salt intended for use in or on foodstuffs which is exported from the Republic of South Africa may contain more than 60 ppm (mg/kg) iodine.

(4) Iodated salt shall be packed in sealed impermeable packaging material.

(5) The label of iodated salt shall contain the word "iodated salt" as part of the name of the product.

(6) Wherever possible the date of iodation shall be indicated on the label of the product.

Corrected by notice No. R. 1231 dd. 18.8.1995

Exemptions

3. These regulations shall not apply to—

(a) food grade salt or other salt intended for use in the manufacture of compound foodstuffs which is packed in bags of 20 kg or more and which is labelled "non-iodated salt";

(b) salt available at pharmacies in packages of 1 kg or less which are labelled "non-iodated salt"; and

(c) low sodium salts as defined in regulation 1.

Repeal

4. Regulation 41 (1) to (10) of the regulations promulgated under the repealed Foods, Drugs and Disinfectants Act, 1929 (Act No. 13 of 1929), and published under Government Notice No. R. 2519 of 10 December 1954, as amended by Government Notices Nos. R. 1618 of 5 October 1962 and R. 295 of 4 March 1966, is hereby repealed.

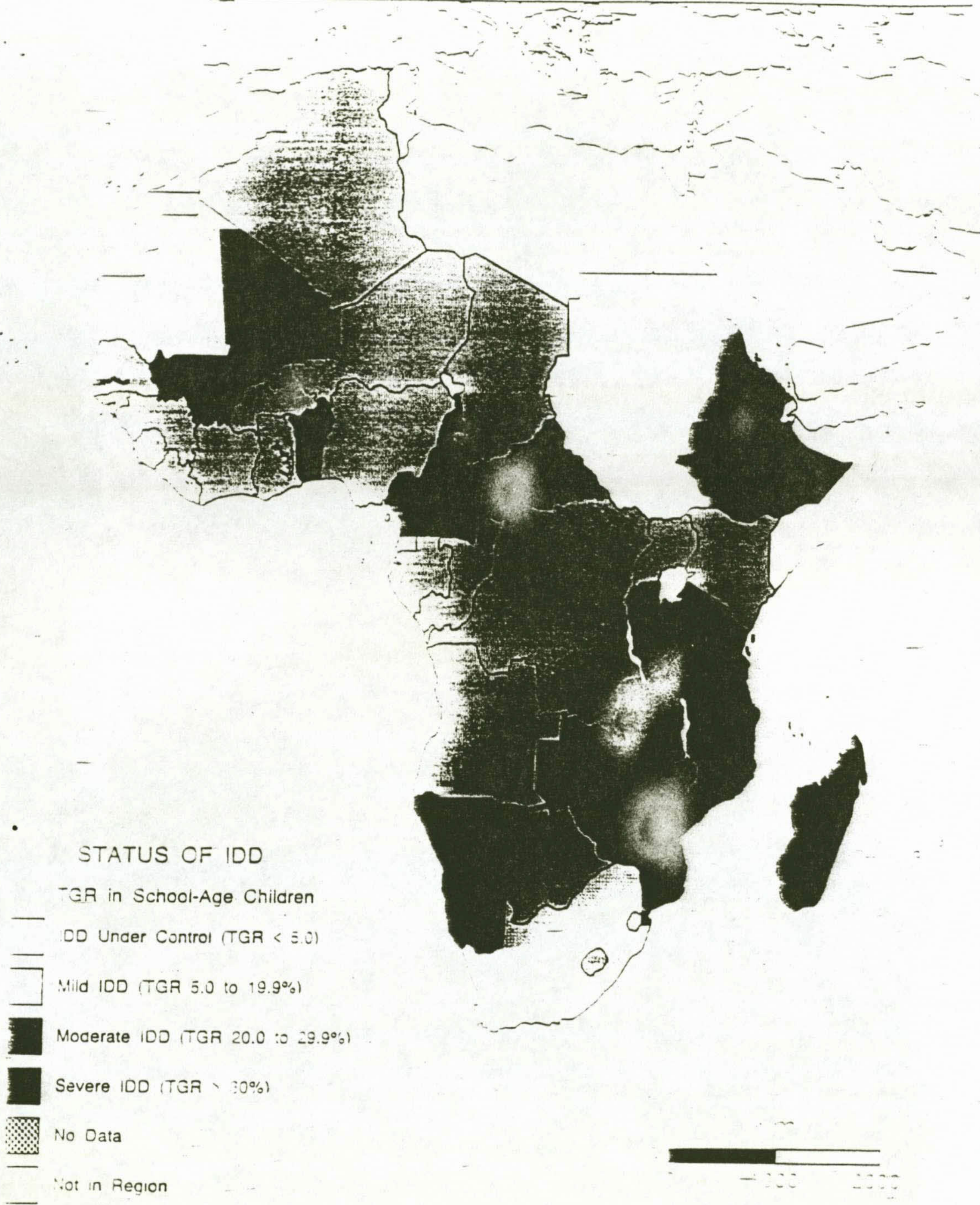
Commencement

5. These regulations shall come into operation on 1 December 1995.

APPENDIX 5: A MAP PRESENTING THE RECENT GOITRE PREVALENCE INFORMATION IN AFRICA

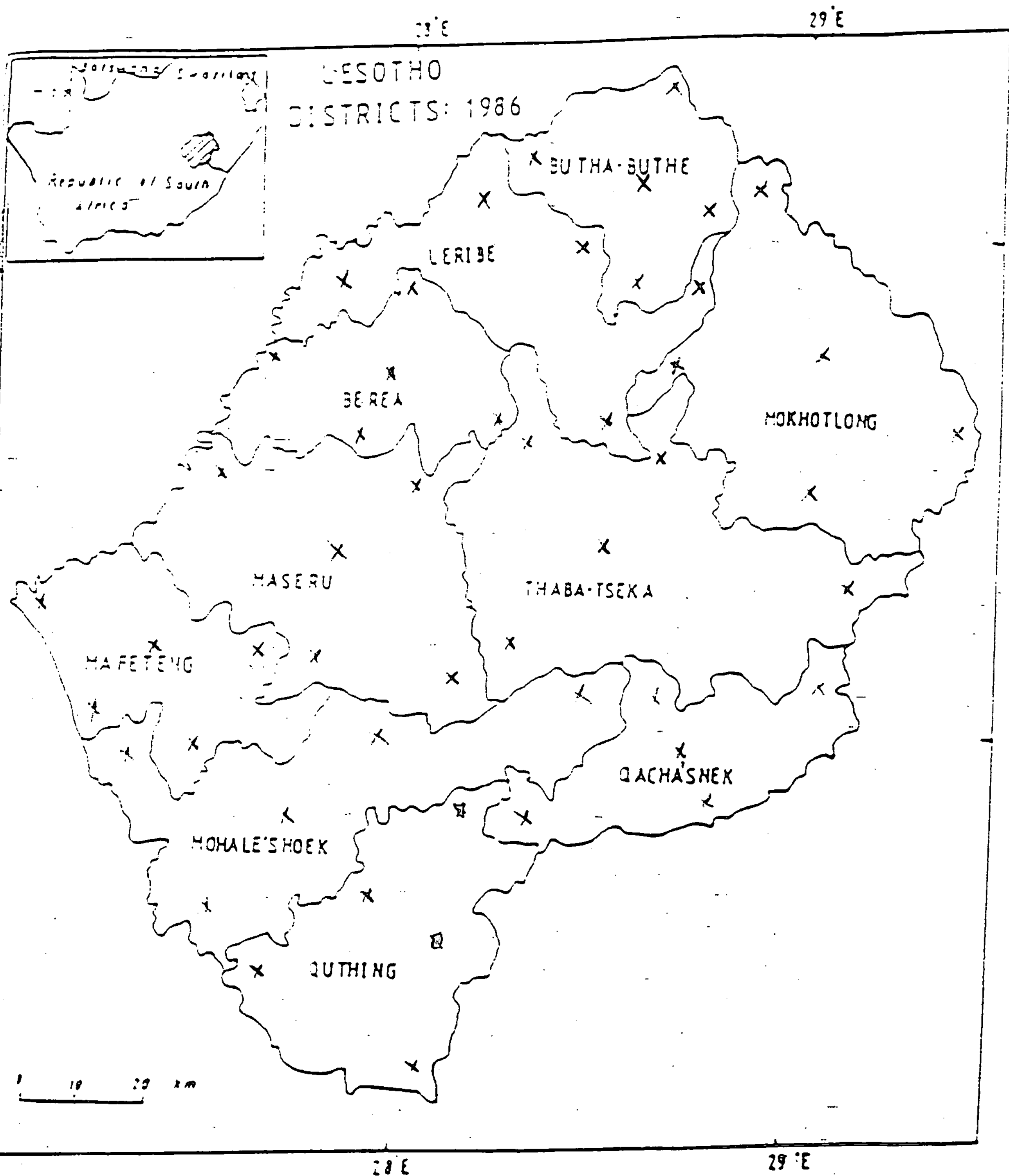
PREVALENCE OF IODINE DEFICIENCY DISORDERS

AFRICAN REGION



Source: WHO, 1993

ENDIX 6 a: THE APPROXIMATE POSITION OF SCHOOLS
UDED IN EACH DISTRICT



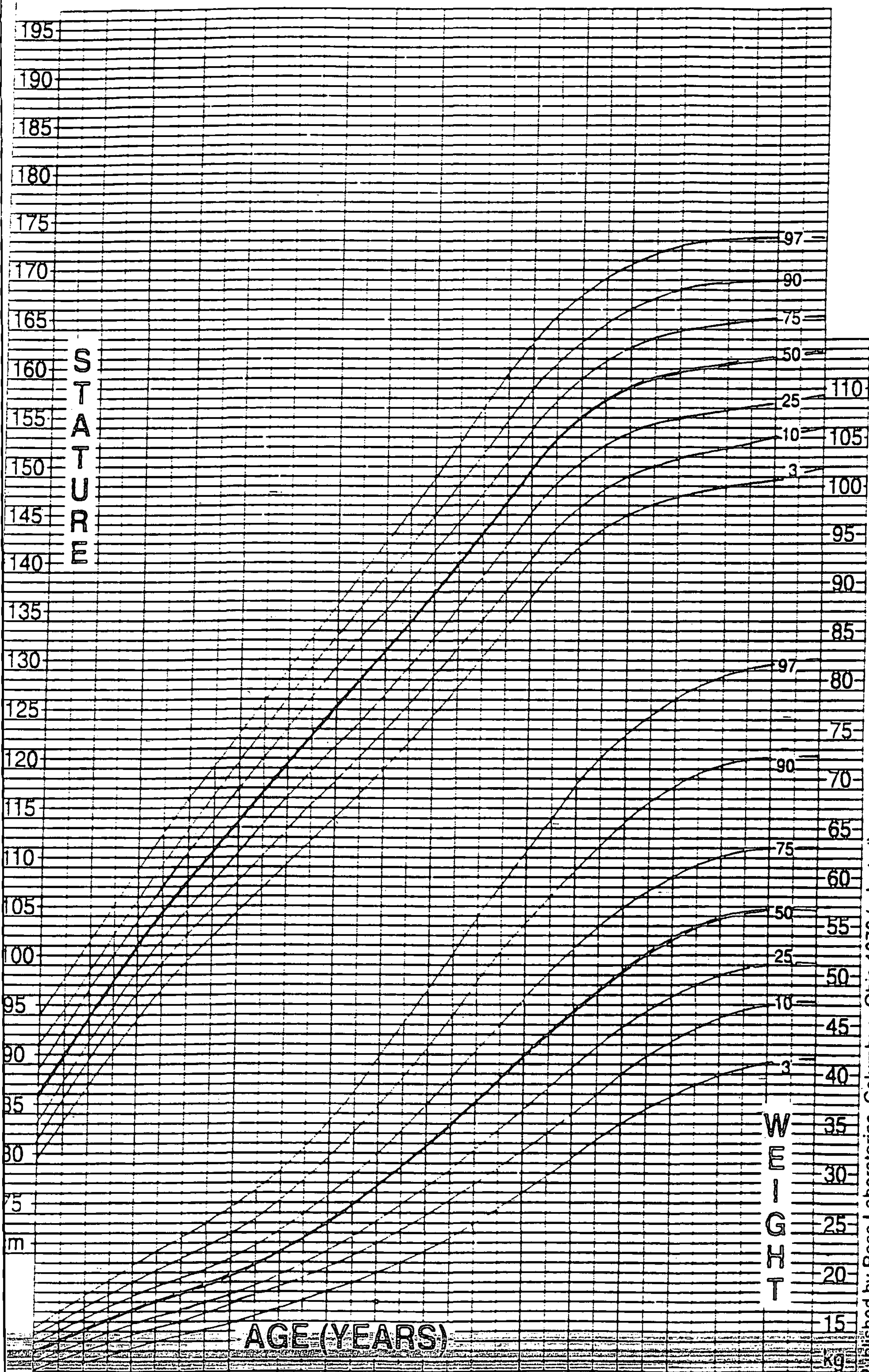
Appendix 6b: LIST OF ALL PRIMARY SCHOOLS INCLUDED IN A SURVEY

DISTRICTS	SCHOOLS
BUTHA-BUTHE	Monontsa
	Mopeli
	Lepatoa
	Sehakalleng
	Lebesa
LERIBE	Maqele
	Rakobeli
	Kolonyama
	Makoa
	Leribe
BEREA	Sebedia
	Rapholo
	Maphele
	Central
	Lithabaneng
MAFETENG	Malumeng
	Kolo
	Makhetheng
	Masemouse
	Qalabane
MASERU	Likalaneng
	Setala
	Marakabei
	Mokhalinyane
	Boqate
MOHALESHOEK	Khitsane
	Theko
	Sekolong
	Matsatsaneng
	Tsepo
QUTHING	Thaba-ntso
	Quthing
	Moyeni
	Masitise

	Mount Moorosi
QACHA'S NEK	Jakopo
	Mapakising
	Manke
	Melikane
	Noasi
MOKHOTLONG	Methating
	Tlokoeng
	Motsitseng
	Koenehelo
	Rafolatsane
THABATSEKA	Linakeng
	Mantsonyane
	Nyane
	Pontseng
	Bereng

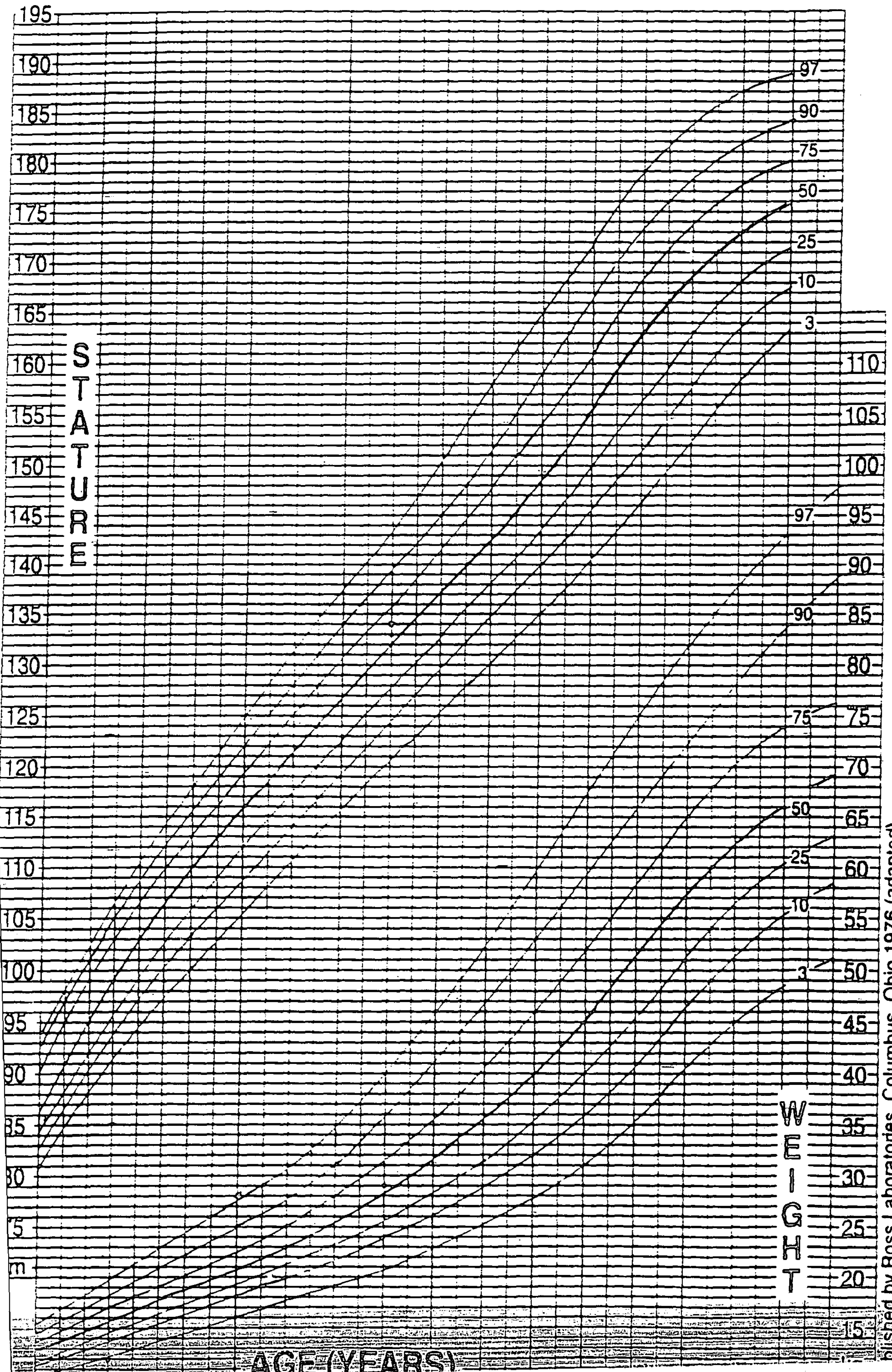
GIRLS: 2 TO 18 YEARS

NAME______________________ FOLDER ______________________



BOYS: 2 TO 18 YEARS

NAME________________ FOLDER ________________



Published by Ross Laboratories, Columbus, Ohio 1976 (adapted)
NCHS Percentiles (adapted)

Appendix 8: STANDIDISED PROCEDURE FOR PALPATION

- CHILD STAND WITH THE HEAD IN A VERTICAL POSITION AND IN AN EXTENDED POSITION
- EXAMINER SIT OR STAND DIRECTLY INFRONT ACCORDING THE HEIGHT OF THE SUBJECT
- EXAMINER INSPECTS THE THYROID AREA AND WITHOUT DELAY USES BOTH THUMBS TO PALPATE VERY GENTLY THE FULL EXTENT OF THE LOBES AND THE ISTHMUS. THE TWO THUMBS ARE PLACED ON EITHER SIDE OF THE SUBJECT'S WINDPIPE, SEVERAL CENTIMETERS BELOW THE NOTCH OF THE THYROID CARTILAGE (ADAM'S APPLE) AND ROLLED GENTLY OVER THE THYROID WHICH LIES NEXT TO THE WIND PIPE
- IT IS ADVISABLE TO ASK THE PATIENT TO RELAX THE NECK MUSCLES BY THROWING THE HEAD SLIGHTLY DOWNWADS AND IT MAY BE HELPFUL TO GET HIM/HER TO SWALLOW SEVERAL TIMES
- A THYROID GLAND WHOSE LATERAL LOBES HAVE A VOLUME GREATER THAN THE TERMINAL PHALANX OF THE THUMB OF THE PERSON BEING EXAMINED WILL BE CONSIDERED

Adapted from: (Demaeyer *et al.*, 1979)

Appendix 9: CONSENT FORM IN SESOTHO

FOROMO EA TUMELLO

BOEMO BA BOTENG BA IODINE BANENG BA LIKOLO TSA MATHOMO BA LILEMO THE ROBONG HO ISA HO TSE LESHOME LE METSO E MELI (1999)

BOITLAMO BA NGOANA/MOTSOALI

Na-- ke itlama hore:

1. Na ngoana sekolo ke kopiloe ho nka karolo lipatlisisong tsa kantoro ea bohokahanyi ba lijo le phepo e nepahetseng.

2. Ke hlaloselitsoe hore:
   - Sepheo sa lipatlisiso tsena ke ho fumana bomeo ba kolu baneng ba lilemo tse robong ho isa ho tse leshome le metso e meli Lesotho, mme mosese oaka o tla nkuoa ho ea etsa lipatlisiso.
   - Tsebo e tla fumanoa e tsa sebelisoa ke muso oa Lesotho ho felisa mathata a bakoang ke khaello ea iodine meleng, mme e tla thusa baahi bohle ba Lesotho.
   - Nka hana ho nka karolo kapa ka tlohela ho araba lipotso.
   - Sephetho se tla lula ele lekunutu feela se tla sebelisoa ke batho ba etsang lipatlisiso.

Litaba tsena li hlalositsoe ho nna ke --------------------(lebitso la mohlalosi), mme ke utluisisa puo eo ho ngotsoeng ka eona. Ke ile ka fuoa monyetla oa ho botsa moo ke sa utluisiseng.

Na motsoali ke lumela ho tiea hore ngoana oaka o tla nka karolo lipatlisisong tsena.
E saennoe-----------------------------------ka la--------19-------

Na/ngoana sekolo ke lumela ka ho tiea ho nka karolo lipatlisong tsena.

E saennoe ------------------------------------ ka la--------19-------

-- ------------------------------

lebitso kapa khatiso ea monoana paki

-- ------------------------------

lebitso la motsoali kappa khatiso ea monoana paki

APPENDIX 9: CONSENT FORM IN ENGLISH

GOITRE PREVALENCE AND URINARY IODINE STATUS OF PRIMARY SCHOOL CHILDREN (8-12YEARS) IN LESOTHO

DECLARATION BY OR ON BEHALF OF THE PARTICIPANT
I--- confirm that:

1. I/The participant has been asked to participate in the above mentioned -research survey of the Food and Nutrition Coordinating Office.
2. It has been explained to me that:

- The purpose of this survey is to collect information of the goitre and urinary status of the children (8-12years) in Lesotho and that my thyroid size will be measured and urine taken for analysis.

- The information obtained from this survey will be used by the Lesotho government to eliminate iodine deficiency disorders, which will help all the people of Lesotho.

- I can refuse to participate in this research and I may withdraw from the study at anytime during an interview.

- The results and information I will give will be kept confidential, but it will be used Anonymously for making known the findings to other scientists/researchers

The information in this consent form was explained/translated to me by -------------------- (name of interviwer/translator) and I confirm that I have a good command in this language and understood the explanations. I was also given the opportunity to ask questions on things I did not understand clearly.

I/ the parent/guardian hereby agree that my child will take part in this research survey
Signed/confirmed at----------------------------on---------19--------

I/the participant(child) hereby agree voluntarily to take part in this research survey.
Signed/confirmed at--------------------------------on -----19-----

---	----------------------------
signature or hand mark of parent/guardian	Witness
---	----------------------------
signature or hand mark of participant	witness

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LYST, JULY 1986, VOL. 111

SHORT PAPERS

proved Routine Method for the Determination of Total Iodine in ine and Milk

es Aumont and Jean-Claude Tressol
A, Laboratoire des Maladies Nutritionnelles, Centre de Recherches Zootechniques et Vétérinaires de ix, 63122 Ceyrat, France

A simple routine method for the determination of iodine in biological fluids is proposed. Destruction of organic matter by alkaline ashing is carried out prior to determination by the Sandell and Kolthoff reaction. The precision is below 8% for urine and milk. Iodine contents as low as 2 ng g⁻¹ (p.p.b.) can be detected.

Keywords: *Iodine determination; milk; urine; Sandell and Kolthoff reaction*

iodine content of biological fluids such as urine and milk is required for nutritional, metabolic and epidemiological es of thyroid disorders. Among the many possible hods, alkaline ashing prior to the final determination of ne by the Sandell and Kolthoff reaction[1] is the most monly used and is the official method of the AOAC.[2] This hod is recommended owing to its precision and operaal simplicity. From an inter-laboratory study, Heckman[3] rted a high between-laboratory relative standard deviation (74.7%) for laboratories using chemical methods. He luded that further investigations are required in order to rove the routine determination of iodine in biological s.

he destruction of organic matter prior to the determination instead of dialysis[4] provides better results, as interfering tances are removed from urine.[5] A rapid and simple hod for the routine determination of iodine in biological ples has been developed that is not time or sample suming. The alkaline ashing procedure of Jones *et al.*[5] has n modified and brucine solution is used to stop the Sandell Kolthoff reaction for greater convenience.[7]

Experimental

aratus

nuffle furnace (Wecstar, Sheffield, UK) with a program- (Eurotherm Automation, Dardilly, France), an autoic shaker (IKA-Werk, Staufen, GDR), an ultrasonic bath nson Instruments, Stamford, CT, USA) and a spectrotometer with a 10-mm flow cell (Beckman Instruments, erton, CA, USA) were used.

gents

the reagents were of analytical-reagent grade and the er used was quartz distilled after de-ionisation.

otassium hydroxide solution. 4 M. Dissolve 56 g of assium hydroxide in 250 ml of water.

rsenious solution. 0.4% *m/V*. Dissolve 4 g of resublimed enic(III) oxide in 50 ml of 1 M potassium hydroxide ition. Dissolve 3 g of sodium chloride in 200 ml of water. 75 ml of sulphuric acid (97% *m/V*) and 500 ml of water. n mix these three solutions and dilute to 1 l with water.

erium(IV) sulphate solution. 0.32% *m/V*. Dissolve 3.2 g erium(IV) sulphate tetrahydrate in 500 ml of water. Add ml of suphuric-acid (97% *m/V*) and dilute to 1 l with water.

rucine solution. 0.5% *m/V*. Dissolve 5 g of brucine ydrate ($C_{23}H_{26}N_2O_4.2H_2O$) in 1 l of 0.3% *V/V* acetic acid.

tandard iodide solutions. Prepare a stock iodide solution 00 µg ml⁻¹) by dissolving 1.308 g of dried (8 h, 105 °C) potassium iodide in 1 l of water. Using an intermediate solution of 50 ng ml⁻¹, prepare working standard solutions of 0, 0.5, 1, 1.5, 2, 2.5, 3, 4 and 5 ng ml⁻¹ in 0.2 M potassium hydroxide solution immediately before use.

Procedures

Alkaline ashing

Into a disposable Corning Pyrex tube (16 × 125 mm) accurately weigh approximately 0.5 g of urine or milk, add 0.5 ml of 4 M potassium hydroxide solution and dry at 105 °C for 20 h. Place the tubes horizontally in a cold muffle furnace as described by Belling,[5] heat at 150 °C for 30 min, then raise the temperature to 600 °C and maintain it for 1 h.

Iodide extraction from ash residue

Add a glass bead and dissolve the ash in 10 ml of water using an ultrasonic bath (10 min), then an automated shaker (10 min). After filtration on a Whatman GF/C glass filter, centrifuge the filtrate at 2500 g for 20 min in a polypropylene tube.

Determination by the Sandell and Kolthoff reaction

In a test-tube mix 1 ml of the supernatant or iodide working solution with 1 ml of arsenious solution. Add 1 ml of cerium(IV) sulphate solution at measured time intervals and place the tube in a heating bath at 30 °C. After 28 min add 0.250 ml of brucine solution at the same time intervals to stop the As - Ce - I reaction.[7] Measure the colour at a wavelength of 420 nm on a spectrophotometer.

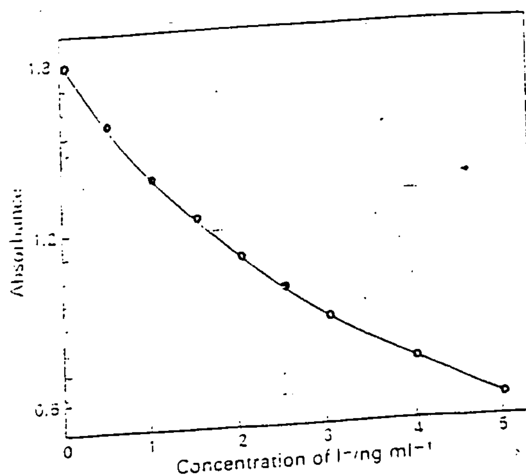

Fig. 1. Calibration graph for determination of iodine. Polynomial curve of third degree

Table 1. Recoveries of iodine-125 and iodide added to urine

Mass of sample/ mg	Recovery ± standard deviation,* % of ^{125}I			I^- added/ ng	Recovery ± standard deviation,* % of added I^-
	After drying	After ashing	After extraction		
250	100.79 ± 0.60 (6)	96.07 ± 2.03 (14)	93.32 ± 0.55 (14)	2.5	94.30 ± 4.07 (10)
500	98.00 ± 1.05 (8)	98.71 ± 2.00 (15)	97.54 ± 1.36 (15)	10.0	93.32 ± 4.54 (8)
750	99.75 ± 1.00 (16)	96.64 ± 2.34 (15)	96.48 ± 1.98 (13)	15.0	95.41 ± 2.55 (9)
1000	99.57 ± 0.36 (7)	97.69 ± 1.78 (15)	93.24 ± 1.67 (14)	20.0	93.08 ± 4.56 (8)

* The figures in parentheses indicate the number of observations.

Table 2. Precision assays: repeatability (within-set variance) and reproducibility (sum of between-set and within-set variances) of iodine determination in urine and milk

Sample	Amount weighed/mg	Mean iodine content*/ng g^{-1}	Repeatability,*† %	Reproducibility,‡
Urine	500	51.7	5.12	6.49 (40)
	750	53.4	3.86	8.73 (20)
Milk 1	500	11.2	6.36	8.83 (15)
Milk 2	500	76.6	2.35	—

* Means of 3 assays of 5–10 determinations.
† Expressed as relative standard deviation.
‡ The figures in parentheses indicate the number of observations.

Table 3. Comparison of the method of Aumont[8] (x) and the proposed method (y)

Sample	Range/ ng g^{-1}	No. of samples	Regression equation	Correlation coefficient
Mare milk	<16	10	$y = 0.63x \pm 1.91$	0.9617
Ewe milk	53–378	10	$y = 1.06x \pm 25.40$	0.9936
Cow milk	3–150	29	$y = 1.09x \pm 0.15$	0.9906
All milk	3–378	49	$y = 0.97x \pm 0.76$	0.9954

Calculation

The calibration graph can be easily interpolated with the polynomial least-squares method of the third degree on a microcomputer (Fig. 1). The absorbance of the sample solutions is read against the calibration graph. The results are expressed in ng g^{-1} (p.p.b.).

Results and Discussion

Accuracy

The accuracy was calculated by measuring the recovery of iodine-125 labelled sodium iodide added to urine before weighing the sample. The recoveries for each step of the method are shown in Table 1, and are in agreement with those found by Jones *et al.*[7] The recoveries of small amounts of potassium iodide added to milk and urine were also measured by the Sandell and Kolthoff reaction. They were between 93.08 and 95.41% for urine (Table 1). The recoveries were lower for milk, 94.40 ± 5.67% for 20 ng g^{-1} of added iodide. This result is similar to that obtained by Aumont[8] using large amounts of milk (10 g).

Precision

The relative standard deviations for working iodide standard solutions at 0.5 and 3 ng ml^{-1} were 5.35 and 2.01%, respectively. The precision was calculated as described by Solari.[9] The repeatabilities were 5.12 and 6.36% (Table 2) for urine and milk, respectively. The reproducibilities for 0.5 g of urine and milk were 6.49 and 8.84%, respectively. This precision is not as good as that recorded by Bakker[10] using a gas - liquid chromatographic method, but similar variations have been noted by Malvano *et al.*[11] and Heckman[12] using neutron-activation analysis, which retains its validity as a ... precision data discussed above, the sensitivities, calculated according to Solari,[9] are 6.3 ng g^{-1} for urine at an iodine level of 51.7 ng g^{-1} and 1.94 ng g^{-1} for milk at an iodine level of 11.2 ng g^{-1}.

Comparison with Aumont's Method[8]

The results of the comparison with the sensitive and precise method of Aumont,[8] which uses 10 g of the sample, are shown in Table 3. For cow and ewe milk, the correlations are better than 0.99 (P <0.001) at medium and high iodine contents. For mare milk, the results obtained by the two methods are well correlated (r = 0.9617, P <0.001), but the slope of the linear curve is 0.63. However, in this experiment, the iodine content was very low (<14 ng g^{-1}).

Conclusion

The alkaline ashing procedure described above offers some advantages over the traditional alkaline dry ashing and acid digestion: low iodine losses, simplicity and rapidity. The method does not use large samples (0.5 g) and one technician can easily perform more than 50 assays per day. The results obtained are in agreement with those recorded by other workers using different methods. The proposed method is rapid, simple, cheap and suitable for the routine determination of iodine in biological fluids. It has a low limit of detection and can be used to determine iodine contents as low as 2 ng g^{-1} for research on endemic goitre.

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NDIX 11: IODINE DEFICIENCY DISORDERS QUESTIONNAIRE PRIMARY SCHOOL CHILDREN (1999)

IODINE DEFICIENCY DISODERS QUESTIONNAIRE FOR PRIMARY SCHOOL CHILDREN (1999)

		Columns
1.	DISTRICT	1-2
2.	NAME OF SCHOOL	3-5
3.	NAME OF CHILD	6-10
4.	AGE OF CHILD IN YEARS	11 - 12
5.	SEX: FEMALE =1. MALE=2	13
6.	GOITRE GRADE: θ=0. 1=1. 2=2	14
7.	URINARY IODINE (μg/l)	15-18
8.	IODINE CONTENT OF SALT	9-22
9.	BUKANA AVAILABLE: Y=1. N=2	23
10.	IODISED OIL CAPSULE RECEIVED IN 1995: ACCORDING TO CHILD: Y=1. N=2. NOT SURE=3	24
	ACCORDING TO BUKANA: Y=1. N=2	25
11.	IODISED OIL CAPSULE RECEIVED IN 1997: ACCORDING TO CHILD: Y=1. N=2. NOT SURE=3	26
	ACCORDING TO BUKANA: Y=1. N=2	27

Appendix 12: WEIGHTS FOR THE ADJUSTMENT FOR THE COUNTRY, ZONES AND DISTRICTS

The weights used to adjust for the whole country

Districts	Ecological zones			
	Mountains	Lowlands	Foothills	Senqu river valley
Thabatseka	0.063305	0.026931	0.009835	0.005750
Leribe	0.037598	0.062116	0.036618	0.013569
Maseru	0.015663	0.085142	0.044755	0.075844
Mokhotlong	0.035332	0.012671	0.004437	0.004301
Buthabuthe	0.019261	0.027301	0.012986	0.008587
Mohaleshoek	0.016176	0.036191	0.017618	0.012683
Berea	0.010499	0.059458	0.011603	0.008731
Quthing	0.028206	0.027087	0.016487	0.007752
Qacha's Nek	0.038433	0.011948	0.004274	0.005114
Mafeteng	0.017482	0.038130	0.017878	0.012523

The weights used to adjust for each zone

Districts	Ecological zones			
	Mountains	Lowlands	Foothills	Senqu river valley
Thabatseka	0.22452	0.06959	0.05572	0.03542
Leribe	0.13335	0.16052	0.20748	0.08778
Maseru	0.05555	0.22002	0.25358	0.49065
Mokhotlong	0.12531	0.03274	0.02514	0.02783
Buthabuthe	0.06831	0.07055	0.07358	0.05555
Mohaleshoek	0.05737	0.09352	0.09982	0.08205
Berea	0.03724	0.15365	0.06574	0.05648
Quthing	0.10004	0.07000	0.09341	0.05015
Qacha's Nek	0.13631	0.03088	0.02422	0.03308
Mafeteng	0.06200	0.09853	0.10130	0.08102

The weights used to adjust for each district

Districts	Ecological zones			
	Mountains	Lowlands	Foothills	Senqu river valley
Thabatseka	0.59979	0.25516	0.09318	0.05187
Leribe	0.25082	0.41438	0.24428	0.09052
Maseru	0.07074	0.38456	0.20214	0.34256
Mokhotlong	0.62268	0.22331	0.07820	0.07581
Buthabuthe	0.28269	0.40068	0.19059	0.12603
Mohaleshoek	0.19568	0.43779	0.21311	0.15342
Berea	0.11628	0.65852	0.12850	0.35465
Quthing	0.34058	0.20730	0.09747	0.64302
Qacha's Nek	0.19991	0.07151	0.08555	0.20324
Mafeteng	0.45512	0.44331	0.20785	0.14560

Appendix 13: THE TOTAL NUMBER OF CHILDREN WHO PARTICIPATED IN ALL THE ECOLOGICAL ZONES IN EACH DISTRICT

DISTRICT	ECOLOGICAL ZONES				
	Mountains	Lowlands	Foothills	Senqu river valley	TOTAL
Thabatseka	237	68	55	92	**452**
Leribe	205	86	75	72	**438**
Maseru	186	84	95	73	**438**
Mokhotlong	182	74	76	81	**413**
Buthabuthe	195	64	73	65	**397**
Mohaleshoek	167	64	65	82	**378**
Berea	145	92	73	63	**373**
Quthing	160	72	64	73	**369**
Qacha's Nek	157	72	63	86	**378**
Mafeteng	163	112	75	85	**435**
TOTAL	**1797**	**788**	**714**	**772**	**4071**

SUMMARY OF THE DISSERTATION

Iodine deficiency has been called the world's most significant cause of mental retardation. Studies conducted since 1960 have indicated iodine deficiency as public health problem in Lesotho. The ICCIDD has been instrumental in focusing the world's attention on IDD and the goal of virtual elimination of IDD as a public health problem by the year 2000 was accepted by the united systems in 1990. This goal was reaffirmed by the 6th World Health Assembly in 1993, which also provided a strategic guidance including emphasis on salt iodisation.

The main objective of this study was to estimate the current IDD situation in Lesotho 5 years after the 1993 National Micronutrient Survey which was followed by iodised oil capsule supplementation as a short term intervention and the introduction of the legislation on universal salt iodisation as a long term intervention.

This was a cross sectional study where stratified random sampling was used to select 5 schools in each of the 10 districts of Lesotho. All children aged 8 to 12 years from the selected schools participated in the study. The size of the thyroid gland was determined by palpation and graded according to the Joint criteria of the WHO/UNICEF/ICCIDD (1994). Casual urine samples were obtained from 10 children in each school in the morning during school hours and frozen until they were analysed for urinary iodine level using the Sandell-Kolthoff reaction involving alkaline ashing at the National University of Lesotho. Using a structured questionnaire, iodised oil supplementation coverage was determined. Salt samples brought by children were also analysed for the presence of iodine using the rapid (spot) test kits. The SAS package was used for statistical analysis of the results at the University of Orange Free State.

4071 primary school children were palpated and responded to the questionnaire, 4071 salt samples and 500 urine samples were analysed. The median urinary iodine concentration of 26.3μg/l, which ranged from 22.3μg/l to 47.9μg/l and from 25.7μg/l to 27.2μg/l in the different districts and ecological zones respectively, indicated moderate IDD. The prevalence of goitre, which increased with age and was higher in females than males, ranged from 2.2 to 8.8 percent and from 2.3 to 6.3 percent in the different districts and ecological zones respectively indicating mild to normal iodine deficiency. The adjusted prevalence of goitre for the whole country was 4.9 percent, indicating the absence of IDD. 94.2 percent of salt samples were iodised. Coverage on iodised oil capsules supplementation, which was 55.1 percent, was not adequate.

Lesotho was found in this study as having mild to moderate IDD, which is still of public health concern according to WHO/UNICEF/ICCIDD (1994). Iodine deficiency was higher in the Mountains than in the Lowlands. However there is an improvement in controlling IDD in Lesotho as observed from the results of the present study and those of the previous studies. The use of iodised salt and iodised oil capsules has most likely contributed to a decrease in the IDD prevalence.

Similar studies using ultrasonography and the titration method need to be conducted in the future. More iodised oil supplementation is recommended in the Mountains and in schools, which never received the capsules and this needs to be coupled with efficient awareness programs. An effective monitoring program needs to be initiated to ensure that the entire population use adequately iodised salt.

Keywords: Iodine deficiency disorders, goitre, urinary iodine, iodised salt, iodised oil capsules.

OPSOMMING

Jodiumtekort is bekend as die belangrikste oorsaak van verstandelike vertraging in die wêreld vandag. Studies wat sedert 1960 uitgevoer is, identifiseer jodiumtekort as 'n publieke gesondheidsprobleem in Lesotho. Die Internasionale Raad vir Kontrole van Jodiumtekortversteurings (ICCIDD) het 'n belangrike rol gespeel om die aandag van die wêreld op jodiumtekortversteurings te plaas, asook aanvaarding van die doelwit deur die Verenigde Sisteme in 1990 om Jodiumtekortversteurings as 'n publieke gesondheidsprobleem teen die jaar 2000 uit te wis. Die doelwit is deur die 6de Wêreld Gesondheidsbyeenkoms in 1993 herbevestig en strategiese riglyne is ook gegee, insluitend beklemtoning van die jodering van sout.

Die hoofdoel van die studie was om 'n beraming te doen van die huidige situasie tov jodiumtekortversteurings in Lesotho, 5 jaar na die 1993 Nasionale Mikrovoedingstofopname. Na die 1993 Nasionale Mikrovoedingstofopname is die gejodeerde oliekapsule supplementasieprogram as 'n korttermyn intervensie en aanvaarding van die wetgewing tov universele soutverryking met jodium as 'n langtermyn intervensie ingestel.

'n Dwarssnitstudie is uitgevoer en 'n gestratifiseerde ewekansige metode van steekproeftrekking is gebruik om 5 skole in elk van die 10 distrikte in Lesotho te selekteer. Al die kinders tussen 8 en 12 jaar van die geselekteerde skole het aan die studie deelgeneem. Die kropgeswelgrootte is mbv palpetering bepaal en gradeer volgens die gesamentlike kriteria opgestel deur die Wêreldgesondheids-organisasie/Verenigdenasies se Kinderfonds/Internasionale Raad vir Kontrole van jodiumtekortversteurings (WHO/UNICEF/ICCIDD, 1994). Luk raak urine monsters is soggens gedurende skoolure van 10 kinders in elke

skool geneem en gevries tot met ontleding dmv Sandell-Kolthoff alkaliese-as reaksie toets deur die Nasionale Universiteit van Lesotho. 'n Gestruktureerde vraelys is gebruik om die gejodeerde oiliesupplementasie dekking te bepaal. Soutmonsters wat deur die kinders na die skool gebring is, is mbv die 'vinnige toetstoerusting'-metode geanaliseer om die teenwoordigheid van jodium in die monsters te bepaal. Die SAS-pakket is deur die Departement Biostatistiek van die UOVS gebruik vir die statistiese ontleding van die resultate.

4071 primêre skoolkinders is palpeer en het vraelyste beantwoord en 4071 soutmonsters en 500 urine monsters is ontleed. Die mediaan van die urinêre jodiumkonsentrasie was 26.3µg/l en het respektiewelik tussen 22.3µg/l en 47.9µg/l en tussen 25.7µg/l en 27.2µg/l in die verskillende distrikte en ekologise zones gewissel, wat op 'n matige voorkoms van jodiumtekortversteurings dui. Die voorkoms van kropgeswel wat met ouderdom toegeneem het was hoër onder seuns as dogters, en het respektiewelik van 2.2 tot 8.8 persent en van 2.3 tot 6.3 persent in die verskillende distrikte en ekologiese zones gewissel wat dui op 'n matige tot normale jodiumtekort. Die aangepaste voorkoms van kropgeswel was vir die hele land 4.9 persent wat daarop dui dat Jodiumtekortversteurings op die grens van uitwissing is. 94.2 persent van die soutmonsters was gejodeer. Die dekking deur die gejodeerde oliesupplementasieprogram was 55.1 persent, wat as ontoereikend beskou word.

In Lesotho is 'n ligte tot matige voorkoms van jodiumtekortversteurings gevind wat steeds as 'n publieke gesondheidsprobleem volgens die WHO/UNICEF/ICCIDD (1994), bestempel word. Die voorkoms van jodiumtekort was hoër in die bergagtige areas as in die laer ligginde gebiede. Die huidige en vorige studies dui op 'n verbetering in die kontrole van jodiumtekortversteurings. Die gebruik van gejodeerde sout en

gejodeerde oiliekapsules het waarskynlik tot die afname in die voorkoms van jodiumtekortversteurings bygedra.

In soortgelyke toekomstige studies behoort die ultrasonografiese en titrasie metodes gebruik te word. Die verspreiding van gejodeerde oliekapsules, gepaard met bewustheidsprogramme in die bergragtige areas en in skole wat voorheen nie die supplementasie ontvang het nie, word aanbeveel. 'n Doeltreffende moniteringsprogram moet inisieer word om te verseker dat die totale populasie gejodeerde sout gebruik.

Sleutelwoorde: Jodiumtekortversteurings, kropgeswel, urinêre jodium, gejodeerde sout, gejodeerde oliekapsules.