PART 2: TECHNICAL NOTES

The technical notes are part two of four parts contained in this module. They provide an introduction to micronutrient malnutrition. The technical notes are intended for people involved in nutrition programme planning and implementation. They provide technical details, highlight challenging areas and provide clear guidance on accepted current practice. Words in italics are explained in the glossary.

Summary

This module provides an overview of micronutrient malnutrition and the methods used for its assessment. The common micronutrient deficiency diseases (MDD) are reviewed and their clinical signs are illustrated. Direct and indirect assessment methods for detecting micronutrient malnutrition are described and the continuing public health significance of micronutrient malnutrition is emphasised.

Key messages

1. Micronutrient malnutrition continues to affect populations in many parts of the world. It is often exacerbated in emergencies and is a significant cause of morbidity, mortality, and reduced human capital.
2. The main cause of micronutrient malnutrition is usually an inadequate dietary intake of vitamins or minerals.
3. Food aid rations have often failed to meet Sphere standards for micronutrient adequacy. A low diversity diet with the absence of micronutrient-fortified foods is a strong predictor of MDD.
4. Infections are an additional and important cause of micronutrient malnutrition and can negatively affect nutritional status by increasing nutrient requirements and reducing nutrient absorption.
5. Globally, iron deficiency anaemia is the most common micronutrient disorder. Large numbers are also affected by iodine and vitamin A deficiencies. These endemic deficiencies often affect populations in emergencies.
6. In addition, epidemics of MDD such as pellagra, scurvy, beriberi, and ariboflavinosis occur in populations affected by severe poverty or experiencing crisis.
7. Assessment of micronutrient deficiencies can be conducted using either direct or indirect approaches.
8. Appropriate ration planning and monitoring of food assistance programmes can greatly reduce the risk of micronutrient malnutrition. Software tools such as NutVal are available to assist in this task.
9. Ensuring that micronutrient deficiency diseases are monitored as part of the health information system is an important part of effective surveillance.
10. Major challenges exist in conducting investigations of MDD outbreaks. Specialist approaches may be required to accurately identify and quantify the extent of MDD.

These technical notes are based on the technical references given in the resource list for the module and the Sphere standards shown in the box below:

Sphere standard

Food Security and Nutrition Assessment Standard 2: Nutrition

Where people are at increased risk of undernutrition, assessments are conducted using internationally accepted methods to understand the type, degree and extent of undernutrition and identify those most affected, those most at risk, and the appropriate response.

Food Security, Food Transfers Standard 1: General nutrition requirements

Ensure the nutritional needs of the disaster-affected population including those most at risk are met.

Key indicators

- There is adequate access to a range of foods, including a staple (cereal or tuber), pulses (or animal products) and fat sources, that together meet nutritional requirements
- There is adequate access to iodised salt for the majority (> 90%) of households
- There is adequate access to additional sources of niacin (e.g. pulses, nuts, dried fish) if the staple is maize or sorghum
- There is adequate access to additional sources of thiamine (e.g. pulses, nuts, eggs) if the staple is polished rice
- There is adequate access to adequate sources of riboflavin where people are dependent on a very limited diet
- There are no cases of scurvy, pellagra, beriberi or riboflavin deficiency
- The prevalence of vitamin A deficiency, iron deficiency anaemia and iodine deficiency disorders are not of public health significance

Source: The Sphere Project (2011). *Humanitarian Charter and Minimum Standards in Humanitarian Response*. Geneva: The Sphere Project.

Introduction

Micronutrient deficiencies are widespread in developing countries with more than two billion people affected. For example, children continue to go blind due to vitamin A deficiency and about 33 per cent of preschool children in developing countries have sub-clinical deficiency.[1] Globally, about 16 per cent of people in the general population are affected by *goitre*, mainly due to insufficient consumption of iodine.[2] Iodine deficiency causes not only widespread endemic goitre but also retards growth and physical development; in its extreme form, this retarded growth is known as *cretinism*. Iron deficiency *anaemia* – characterised by breathlessness and fatigue – is highly prevalent worldwide with about 1.6 billion affected people. Unlike deficiencies in vitamin A and iodine, anaemia occurs widely in both industrialized and developing countries.

Micronutrient deficiencies occur more frequently in individuals on a monotonous or restricted diet or in those with infections. Both these problems are characteristic of most emergency situations. Micronutrient deficiencies have been reported for years in emergency settings and especially in refugee camps, where they have been most frequently assessed (see table 2). Some deficiency diseases, such as anaemia and vitamin A deficiency, primarily affect children and women, while others, such as pellagra, are found more frequently in adult females and males. Micronutrient deficiencies have also been documented in adolescents in African refugee camps.

Micronutrient deficiencies have many detrimental effects such as an increase in *morbidity* (illness) and *mortality* (death) risk as well as impaired growth and mental development. Eradicating micronutrient deficiencies is a fundamental component of any public health intervention.

This module covers the recognition and assessment of micronutrient malnutrition and micronutrient deficiency diseases. Approaches to treatment and prevention strategies for micronutrient deficiencies are covered in module 14.

[1] WHO (2009) *Global prevalence of vitamin A deficiency in populations at risk, 1995-2005* World Health Organisation: Geneva

[2] WHO (2004) *Iodine Status Worldwide* World Health Organisation: Geneva

Table 1: Definitions

Definitions	Concepts
Micronutrient malnutrition: The existence of sub-optimal nutritional status due to a lack of intake, absorption, or utilisation of one or more vitamins or minerals. Excessive intake of some micronutrients may also result in adverse effects.	Micronutrient malnutrition can exist even when the energy and macronutrient needs of an individual are met. For that reason it is often referred to as 'hidden hunger'. People may appear well fed but still be suffering from debilitating and life threatening malnutrition.
Micronutrient deficiency disease (MDD): A clinical disease that arises due to a lack of intake, absorption, or utilisation of one or more vitamins or minerals.	When certain micronutrients are severely deficient specific clinical signs and symptoms may develop. The classic nutritional diseases such as scurvy, beriberi and pellagra are good examples of these sorts of disease.

Note: The term micronutrient deficiency disorder is also used when referring to micronutrient malnutrition and MDD.

Table 2: Examples of micronutrient deficiencies reported in emergency situations

	Location	Years
Vitamin C deficiency	Somalia* Sudan* Ethiopia* Kenya* Afghanistan	1982, 1985 1984, 1991 1989 1994, 1996 2001, 2002
Vitamin A deficiency	Sudan* Kenya* Nepal* Ethiopia* Uganda*	1985, 1987 1998, 2001 1999 2001 2001
Niacin deficiency	Malawi* Angola (internally displaced persons) Angola	1989, 1990, 1991, 1996 1999, 2000 2002
Anaemia	Kenya* Nepal* Uganda* Ethiopia* Algeria* Thailand* Jordan* Lebanon* Syria* Gaza* West Bank*	1998, 2001 1999 2001 2001 2002 2001-2002 1990 1990 1990 1990 1990
Thiamine deficiency	Thailand* Nepal* Kenya (internally displaced persons)	1992 1994-1995 2000

Source: NICS (2007) *Assessing micronutrient deficiencies in emergencies: Current practice and future directions* Geneva: SCN

* In refugee camps

The main micronutrients and associated deficiency diseases

Micronutrients include all vitamins and the minerals that are essential for human health. They are required in only small amounts but, nonetheless, are essential for life and needed for a wide range of normal body functions and processes. Vitamins are either water-soluble (e.g. the B vitamins and vitamin C) or fat-soluble (e.g. vitamins A, D, E and K). Essential minerals include iron, iodine, zinc, calcium, and a large number of others.

Micronutrients are found in different amounts in different foods. Some micronutrients are widely available in a range of foods. Others, such as vitamin C, may be found only in certain types of food. A deficiency of a particular micronutrient is more common when it is only found in a limited range of foods and these are not available to the whole population.

Micronutrients can be categorized as either Type 1 or Type 2 nutrients.

Type 1 nutrient deficiencies result in specific deficiency diseases, do not always affect growth, but will affect metabolism and immune competence before signs are apparent. This category of nutrients includes vitamins A, B1, B2, B3, B6, B12, C, D, and folic acid, as well as iron, calcium, copper, iodine, and selenium.

Type 2 nutrient deficiencies do not show specific clinical signs. They affect metabolic processes and result in growth failure, wasting, increased risk of oedema, and lowered immune response. This category of nutrients includes sulphur, potassium, sodium, magnesium, zinc, phosphorus, water, essential amino acids, and nitrogen deficiencies.

Table 3 lists nine of the most important micronutrients, their functions, sources, and signs of deficiencies. Bear in mind that there are also other micronutrients (e.g. selenium and the others listed above) that are extremely important for human nutrition, but these nine are considered to be of particular importance in an emergency context.

The micronutrient requirements of an individual depend on age and sex. Nutrient requirements may also increase during critical period of rapid growth and development (pregnancy, lactation, infancy and early childhood) as well as during certain illnesses and diseases (such as malaria, diarrhoea, tuberculosis).

Annex 1 contains tables of vitamin and mineral requirements recommended by the World Health Organisation (WHO) and the Food and Agricultural Organisation (FAO) for populations.

While we are usually concerned about people not receiving an adequate amount of micronutrients in their diet, it should not be forgotten that there is a risk of toxicity with excessive intakes of some micronutrients. For example, a high intake of vitamin A is especially dangerous for pregnant women as damage to the growing baby can occur. For this reason, high dose supplements of vitamin A are not usually given to pregnant women unless they are exhibiting clinical sign of deficiency (see module 14).

Approaches to the assessment of micronutrient deficiencies

There are two main approaches to assessing micronutrient deficiencies in emergencies, indirect and direct assessment.

- **Indirect assessment** involves the estimation of nutrient intakes at a population level and extrapolating from this the risk of deficiency and the likely prevalence (rate) and public health seriousness of MDD.
- **Direct assessment** involves the measurement of actual clinical or sub-clinical deficiency in individuals and then using that information to give a population estimate of the prevalence of the MDD.

Indirect Assessment

The indirect assessment approach involves two stages. Firstly, the dietary intake of the population of concern needs to be measured or estimated and, secondly, this intake has to be compared with the nutrient requirements of the population.

Nutrient intake values (NIV) provide guidance about the nutrient intakes that healthy individuals require. Countries may publish different NIV and there may be large differences in their values.

The NIVs that are currently recommended by WHO and FAO are called Reference Nutrient Intakes (RNI). These RNI were published in 2004 and are given in the table in Annex 1. It is important to note that older WHO recommendations for emergency affected populations, called Safe Levels of Intake (SLI), are still sometimes used for calculating nutrient requirements. Using these will give you somewhat different requirement figures so it is important that this is borne in mind.

To obtain population nutrient requirements, assumptions have to be made about the demographic profile of the population, the bioavailability of nutrients within the diet, the energy requirement of the population, and allowances made for population health status.

Assessing these factors in emergencies is not easy and usually impossible in the early stages of the emergency. The use of the population planning figures in indirect assessment of the risk of micronutrient deficiencies is therefore usually essential. Table 4 gives the planning figures for a general food ration that are designed to meet the needs of a population according to Sphere. This planning figure should be revised as necessary based on an assessment of the demographic structure, activity level, ambient temperature, and health status of the population (see module 11 for details).

Table 3: Functions, sources, and signs of deficiency for selected micronutrients

Vitamin A

Function	Forms and measurement units	Sources	Effects of storage and preparation
Vitamin A is a fat-soluble vitamin required for the normal functioning of the visual system, growth and development, maintenance of epithelial cell integrity, immune function, and reproduction.	Vitamin A is present in food in two forms: – Preformed vitamin A (retinol) contained in foods of animal origin – Provitamin A carotenoids (e.g. beta-carotene) contained in plant foods Human nutritional requirements are usually expressed as µg of retinol equivalents (RE). Vitamin A in supplement capsules is measured in international units (IU). 1.0µg RE = 3.3 IU	Retinol is chiefly found in dairy products, liver and some fatty fish. Carotenes are found in yellow and red fruits and vegetables, and in green leafy vegetables, especially the green outer leaves. Vitamin A is absent in vegetable oils with the exception of fortified margarines and red palm oil which contain provitamin A.	Both retinol and carotene are stable to ordinary cooking methods though some losses may occur at temperatures above 100°C as when butter or palm oil is used for frying. Vitamin A is sensitive to oxidation, so foods that are dried in the sun lose much of their vitamin A potency. Vitamin A-rich foods should be stored out of direct sunlight.

Signs of deficiency	At risk groups	Effects of high intakes/toxicity
Vitamin A deficiency results in xerophthalmia, which affects the eyes. The main signs in order of severity are: • Night blindness (XN) • Bitot's spots (X1B) Foamy accumulations on the conjunctiva (inner eyelids), that often appear near the outer edge of the iris. • Corneal xerosis (X2) Dryness, dullness or clouding (milky appearance) of the cornea. • Keratomalacia (X3) Softening and ulceration of the cornea. This is sometimes followed by perforation of the cornea, which leads to the loss of eye contents and permanent blindness. Ulceration and perforation may occur alarmingly fast (within a matter of hours). The letters and numbers in brackets, e.g. X1B, are the codes for the different forms of xerophthalmia. Vitamin A deficiency in children is also associated with an increased risk and severity of morbidity and increased risk of mortality.	Vitamin A deficiency occurs widely in developing countries with the highest prevalence rates in the regions of South East Asia and Africa. Children suffering from measles, diarrhoea, respiratory infections, chickenpox and other severe infections are at increased risk of vitamin A deficiency.	Vitamin A toxicity can be classified into acute, chronic or teratogenic: – Acute toxicity results from one or several very large doses of vitamin A. The signs (vomiting, diarrhoea, bulging fontanel in children, headaches) usually disappear after a few days. – Chronic toxicity occurs with recurrent excessive intakes over a period of months to years of excessive doses of vitamin A. – Teratogenic toxicity in pregnant women may lead to foetal loss, and birth defects. Women who are or may become pregnant should not consume more than 3,000µg RE per day.

Table 3: Functions, sources, and signs of deficiency for selected micronutrients (continued)

Vitamin B1 (Thiamine)

Function	Forms and measurement units	Sources	Effects of storage and preparation
Thiamine is water-soluble vitamin that functions as a coenzyme in the metabolism of carbohydrates and branched-chain amino acids.	Thiamine (can also be spelt Thiamin) exists in one main form and human nutritional requirements are usually measured in milligrams (mg)	Thiamine is widely distributed in animal and plant tissues. The only rich sources, however, are liver, yeast and legumes.	Large losses of thiamine occur during milling or pounding when the outer layer of cereals is lost. Parboiling rice prior to milling reduces losses as thiamine is driven into the interior of the grain. There are losses when cooking water is discarded.

Signs of deficiency	At risk groups	Effects of high intakes/toxicity
Thiamine deficiency results in beriberi. Four forms of beriberi that are commonly due to low intake of vitamin B1 in developing countries are described: 1 Wet beriberi: – Anorexia (loss of appetite) and ill-defined malaise – Tenderness in the calf muscles and 'pins and needles' – Oedema spreading from legs to the face and trunk – Restlessness and breathlessness with rapid pulse and palpitations 2 Dry beriberi: – Polyneuropathy (general dysfunction of the nervous system) with loss of feeling in the feet and diminished touch sensation – Muscles become progressively wasted and weak, and walking becomes difficult 3 Infantile acute cardiac beriberi: – Peak prevalence in breast-fed babies of 1-3 months of age. – Colic-like symptoms with screaming bouts, restlessness, anorexia and vomiting – Oedema – Breathlessness with signs of heart failure and increased pulse rate – Heart failure eventually leads to death 4 Aphonic beriberi: – Peak prevalence in 4-6 month old children. Voice changes with a cry that becomes more and more hoarse until no sound at all is produced. Restlessness and breathlessness, Oedema Thiamine deficiency also results in Wernicke-Korsakoff syndrome, a condition frequently associated with chronic alcoholism	Populations who consume non-parboiled polished rice as a staple are at risk. This includes breastfed babies whose mothers are eating a deficient diet. Those at risk also include those who consume diets rich in anti-thiamine factors, such as sulphites (added in food processing), raw fish and shellfish, and betel nuts.	Thiamine has a low toxicity and there are no established upper limits for intake.

Table 3: Functions, sources, and signs of deficiency for selected micronutrients (continued)

Vitamin B2 (Riboflavin)	Function	Forms and measurement units	Sources	Effects of storage and preparation
	Riboflavin is a water-soluble vitamin required for the normal functioning of many enzymes as well as the development and maintenance of epithelial cell integrity.	Riboflavin exists in one main form and human nutritional requirements are usually measured in milligrams (mg)	Riboflavin is widely distributed in food but is in low levels in most foods that are not of animal origin. Rich sources include dairy products, eggs, lean meats, and legumes.	Riboflavin is heat stable but can be leached out of food during cooking and is sensitive to light and alkaline solutions.
	Signs of deficiency		**At risk groups**	**Effects of high intakes/toxicity**
	Riboflavin deficiency leads to ariboflavinosis, a deficiency disease characterised by angular stomatitis. Angular stomatitis affects the corners of the mouth which can become split or cracked. The lesions may become infected with pathogens such as candida albicans and have a whitish appearance. Cheilosis, scaling and cracking of the surface of the lips may be seen. Glossitis, inflammation or swelling of the tongue is also sometimes reported.		Populations dependent on rice as a staple. Ariboflavinosis is found extensively in south Asia as well as in parts of Africa. Those who are at risk have a limited availability of food in general and a low consumption of dairy products.	Riboflavin is well tolerated and has a very low toxicity.

Table 3: Functions, sources, and signs of deficiency for selected micronutrients (continued)

Vitamin B3 (Niacin)

Function	Forms and measurement units	Sources	Effects of storage and preparation
Niacin is water-soluble and plays a central role in the utilization of food energy. It is also known as vitamin PP (pellagra preventative factor).	Niacin exists in the forms of nicotinic acid and nicotinamide. It can be synthesized from the amino acid tryptophan. On average, 1 mg of niacin is derived from 60 mg of dietary tryptophan. Niacin is usually measured as milligrams (mg) of preformed niacin, or as mg Niacin Equivalents (NE), which includes the niacin that can be made by the body from tryptophan. ANE are Available Niacin Equivalents which allows for the fact that niacin from cereal grains such as maize has a low biological availability.	Niacin is widely distributed in plant and animal foods, but only in small amounts, except in meat (especially offal), fish, wholemeal cereals and pulses.	Cooking causes little actual destruction of niacin but considerable amounts may be lost in the cooking water and 'drippings' from cooked meat if these are discarded.

Signs of deficiency	At risk groups	Effects of high intakes/toxicity
Niacin deficiency results in pellagra, which affects the skin, gastro-intestinal tract and nervous systems. For this reason, it is sometimes called the disease of the 3Ds: dermatitis, diarrhoea and dementia: – Dermatitis develops as redness and itching on areas of the skin exposed to sunlight – The redness develops into a distinctive 'crazy pavement' pattern and is symmetrical and bilateral. – Where dermatitis affects the neck, it is sometimes termed 'Casal's necklace' – A distinctive 'butterfly sign' around the nose and eyes is sometimes seen – Complaints of the digestive system included diarrhoea, nausea and sometimes constipation – Disturbances of the nervous system include insomnia, anxiety weakness, tremor, depression and irritability – Dementia or delirium is sometimes seen Pellagra may be fatal if not treated, the 4th D being death.	Populations, who consume maize as their staple without processing the maize with alkali to release niacin, are at risk of developing pellagra. Processing maize with alkali is commonly practiced in South America but is rarely done in Africa, where pellagra is endemic. Where niacin rich foods, such as peanuts, have not been provided in emergency food rations pellagra has occurred. Adults are at higher risk than children and women more than men.	High doses of nicotinic acid can cause vasodilatation and flushing and gastrointestinal effects such as dyspepsia, diarrhoea and constipation. Long term, very high doses (3-9g per day), may result in hepatotoxicity.

Table 3: Functions, sources, and signs of deficiency for selected micronutrients (continued)

Vitamin C

Function	Forms and measurement units	Sources	Effects of storage and preparation
Vitamin C is water-soluble and plays a crucial role in the maintenance of connective tissue, supports immune function, and promotes wound healing. It also enhances the absorption of iron in the gut.	Vitamin C is often called ascorbic acid. However, vitamin C has two chemical forms; ascorbic acid and dehydroascorbic acid. Human nutritional requirements are usually expressed as mg per person per day.	Vitamin C is widely distributed in plant and animal foods and is found in high concentrations in fruits and vegetables, e.g. guava and citrus fruit.	Vitamin C is not very stable and may be oxidised during food storage, preparation, and cooking.
Signs of deficiency		**At risk groups**	**Effects of high intakes/toxicity**
Clinical vitamin C deficiency results in scurvy. Classic signs include: • Lack of energy, weakness, irritability, and weight loss • Swollen and bleeding gums • Perifollicular haemorrhages • Bruising • Skeletal changes in children If left untreated, Scurvy can be fatal.		Populations with a low intake of fresh fruit and vegetables. In food aid dependent populations fortified blended foods may be the only source of vitamin C.	Very high doses (over 2000mg in adults) may result in nausea and diarrhoea, interfere with the antioxidant-prooxidant balance in the body, and, in patients with thalassemia or hemochromatosis, promote iron overload.

Table 3: Functions, sources, and signs of deficiency for selected micronutrients (continued)

Vitamin D

Function	Forms and measurement units	Sources	Effects of storage and preparation
Vitamin D is fat-soluble and its active form is involved in calcium homeostasis and bone mineralisation.	Vitamin D is found in two forms: • Ergocalciferol (vitamin D2) • Cholecalciferol (vitamin D3) Cholecalciferol is the form naturally made in the human body. Requirements for Vitamin D are usually expressed as µg per person per day.	Vitamin D is mainly synthesized in the body when the skin is exposed to sunlight. Other natural dietary sources that may be important include salmon, sardines, Tuna, egg, fish liver oil, mushroom and dairy products.	Storage, processing and preparation have no adverse effects on vitamin D content.
Signs of deficiency		**At risk groups**	**Effects of high intakes/toxicity**
Vitamin D deficiency results in rickets, a deficiency disease that affects young children. Typical signs include: • Delayed closure of fontanelles • Swollen wrists and ankles • Squared head caused by bossing of frontal bone structure • Swelling of the ends of the ribs ('rachitic rosary') • Decreased muscle tone • Spinal deformity Severe signs include: • Spontaneous fractures • Bowing of legs • Tetany (twitching in feet and hands) and convulsions Rachitic children show reduced bone growth, are anaemic, and prone to respiratory infections. Rickets may also be caused by calcium deficiency.		Rickets is endemic in most Middle Eastern countries in a band going from Morocco to Pakistan and can occur as far south as Ethiopia. It is also common in parts of eastern Europe. Lack of exposure to the sun in combination with a diet low in preformed vitamin D and high in phytic acid (e.g. bread) can cause rickets. Populations living in desert areas where atmospheric dust acts as a filter for ultra-violet light are susceptible, particularly when people stay inside to avoid the heat of the day and wear extensive clothing. Populations who are forced to remain inside due to shelling or fighting are also at risk.	Infants are most at risk of developing hypervitaminosis D. Hypercalcaemia is the main adverse affect and may result from doses above 45µg per day.

Table 3: Functions, sources, and signs of deficiency for selected micronutrients (continued)

Iron

Function	Forms and measurement units	Sources	Effects of storage and preparation
Iron has three major roles in the body. Firstly, it is necessary for the synthesis of haemoglobin (Hb), which carries oxygen to the body's cells and transports carbon dioxide from the tissues to the lungs. Secondly, it is a component of myoglobin (a muscle protein), and thirdly it is required for the functioning of many enzymes.	Iron is a chemical element and is found in two forms in food: (i) Heam iron: Found in animal source foods bound to haem protein in blood and muscle. (ii) Non-heam iron: Found mainly in plant foods. Human nutritional requirements are usually expressed as milligrams (mg) per day. The chemical symbol for iron is Fe and it exists in two ionic forms, as ferrous (Fe2+) and ferric (Fe3+) ions.	Meat, cereals, vegetables and fruit all contain iron, but haem iron is much more easily absorbed than non-haem iron. Consuming vitamin C at the same time will increase absorption of iron. Eating phytate rich foods such as chapattis, or drinking tea which contains poly-phenols, will decrease absorption.	Iron is stable during food preparation.

Signs of deficiency	At risk groups	Effects of high intakes/toxicity
Lack of iron eventually results in iron-deficiency anaemia. Typical signs are: • Pale conjunctivae (inner eyelid), nail beds, gums, tongue, lips and skin • Tiredness • Headaches • Breathlessness Women with severe anaemia carry a high risk of complications during childbirth. Iron deficiency during infancy and early childhood also leads to impaired cognitive development. Economic productivity and educational achievement in populations is reduced by iron deficiency anaemia.	At risk groups are: • Women of child-bearing age (because of blood loss through menstruation) • Pregnant and breastfeeding women (because of increased iron requirements) • Babies exclusively breastfed beyond the age of 6 months (because iron in breast milk is inadequate) • Babies given cow's milk (because of intestinal blood losses) • Weaning-age children (because of inappropriate weaning diets) • Regions where malaria and intestinal parasitic infestation are prevalent are at risk.	The acute toxic dose in infants is approximately 20mg per kg body weight and the lethal dose is about 200-300mg per kg. In adults, a 100g dose of iron is lethal.

Table 3: Functions, sources, and signs of deficiency for selected micronutrients (continued)

Iodine

Function	Forms and measurement units	Sources	Effects of storage and preparation
Iodine is an essential constituent of hormones produced by the thyroid gland in the neck. In the foetus, iodine is necessary for the development of the nervous system.	Iodine is a chemical element. In fortified salt it is found as Potassium Iodate or Potassium Iodide. Human nutritional requirements are usually expressed as µg per person per day. The chemical symbol for iodine is I.	The level in the soil determines the iodine content of plants and animals. Areas where frequent flooding or drainage has leached iodine from the environment are prone to iodine deficiency. The richest natural source of iodine is seafood.	Cooking reduces the iodine content, with about half being lost during boiling but only about 20% being lost during frying or grilling. Iodised salt will lose its iodine if left uncovered or exposed to heat.

Signs of deficiency	At risk groups	Effects of high intakes/toxicity
Iodine deficiency causes a range of abnormalities including goitre (swelling of the thyroid gland in the neck) and cretinism, which occurs in the offspring of women with severe deficiency. Goitre: Grade 0 No palpable (can't feel) or visibly enlarged thyroid Grade 1 A palpable but not visibly enlarged thyroid with the neck in a normal position Grade 2 A palpable and visibly enlarged thyroid with the neck in a normal a Position Cretinism: There are 2 types of cretinism Neurological cretinism: • Mental deficiency • Deaf mutism • Spasticity • Ataxia (lack of muscular coordination) Hypothyroid or myxoedematous cretinism: – Dwarfism – Hypothyroidism (small thyroid gland)	Goitre is endemic in many mountainous areas of Europe, Asia, the Americas and Africa where there is limited access to seafood or iodised salt. Goitre is also associated with the consumption of goitrogenic foods such as cassava. The prevalence of goitre increases with age and reaches a peak during adolescence. Goitre tends to affect girls more than boys and women more than men because of increased activity of the thyroid gland during pregnancy.	High iodine intakes can cause toxic modular goitre and hyperthyroidism. Iodine induced hyperthyroidism (IIH) may be a particular problem in a population that has been previously deficient and has high levels of iodine introduced into their diet.

Table 3: Functions, sources, and signs of deficiency for selected micronutrients (continued)

Zinc

Function	Forms and measurement units	Sources	Effects of storage and preparation
Zinc is an essential mineral that is important in immunity and growth	Zinc is an element that is found in various compounds. Human nutritional requirements are usually expressed as mg per person per day. The chemical symbol for zinc is Zn and it occurs as a divalent ion, Zn^{2+}.	Zinc is found in a wide variety of foods with rich sources including red meat, whole grains, eggs and nuts.	As zinc is not a labile an element and is retained during most forms of food storage, processing and cooking.
Signs of deficiency		**At risk groups**	**Effects of high intakes/toxicity**
Zinc deficiency is associated with no-specific signs such as growth failure, diarrhoea, and skin lesions. Dwarfism and hypogonadism have been shown to result from deficiency. Assessment of zinc status in populations and individuals remains very difficult. Indicators of zinc deficiency recommended by the International Zinc Nutrition Consultative Group include: the prevalence of serum zinc concentration less than the age/sex/time of day-specific cut-offs; the prevalence (or probability) of zinc intakes below the appropriate estimated average requirement (EAR); and the presence of a low height-for-age in 20% or more of the population.		Populations with low diet diversity and diets high in fibre and/or phytate (e.g. vegetarians) are at risk of deficiency. Sub-groups at particular risk are infants, adolescents and pregnant women. Patients with genetic diseases such as acrodermatitis enteropathica and sickle cell anaemia are at special risk of zinc deficiency.	High doses of elemental zinc ranging from 100 to 150mg/day for prolonged periods interferes with copper metabolism and causes low blood copper levels, red blood cell microcytosis, neutropenia, and impaired immunity. Ingesting larger amounts (200 to 800mg/day), e.g. by consuming acidic food or drink from a galvanized (zinc-coated) container, can cause anorexia, vomiting, and diarrhoea.

Table 4: Current standards for population nutritional requirements – to be used for planning purposes in the initial stage of an emergency

Nutrient	Minimum Population Requirements[3, 4]
Energy	2,100 kcal
Protein	53g (10% of total energy)
Fat	40g (17% of total energy)
Vitamin A	550µg RAE
Vitamin D	6.1µg
Vitamin E	8.0mg alpha-TE
Vitamin K	48.2µg
Vitamin B1 (Thiamin)	1.1mg
Vitamin B2 (Riboflavin)	1.1mg
Vitamin B3 (Niacin)	13.8mg NE
Vitamin B6 (Pyidoxine)	1.2mg
Vitamin B12 (Cobalamin)	2.2µg
Folate	363µg DFE
Pantothenate	4.6mg
Vitamin C	41.6mg
Iron	32mg
Iodine	138µg
Zinc	12.4mg
Copper	1.1mg
Selenium	27.6µg
Calcium	989mg
Magnesium	201mg

Source: The Sphere Project (2011). Humanitarian Charter and Minimum Standards in Humanitarian Response. Geneva: The Sphere Project.

[1]Alpha-TE – alpha-tocopherol equivalents

RAE – retinol activity equivalents

NE – niacin equivalents

DFE – dietary folate equivalents

The micronutrient content of food aid rations

The micronutrient content of general rations distributed in many food aid operations has been the subject of criticism for a number of years. Recommended rations generally include a cereal, pulses, oil, salt and multi-micronutrient fortified blended food.

Fortified blended food has been added to general rations since the mid-nineties to improve its micronutrient content. It is also recommended by the United Nations High Commissioner for Refugees (UNHCR) and other technical agencies that salt is fortified with iodine, oil with vitamin A and D and wheat and maize flour with multi-micronutrients. However, analysis of the micronutrient content of standard rations still reveals the presence of deficiencies in micronutrients.

This problem persists for a number of reasons. Fortification of the staple cereal in food aid rations is still uncommon and, where food fortification does happen, the micronutrient mix that is added is often not appropriately designed to fill the nutrient gaps that exist. Where fortified blended food is included in general rations it is often included either in low quantity or quality and may be inadequate to bring the ration up to standard. Lastly, rations are often supplied in the absence of any complementary food items such as fresh vegetables or fruit.

A memorandum of understanding (MOU) exists between the World Food Programme (WFP) and UNHCR that guides food aid policy in refugee operations This MOU requires UNHCR to supply complementary food items where needed. The MOU was agreed in 2002 and is likely to be revised during 2011.

A MOU (1996) also exists between WFP and UNICEF which includes the objectives to *"prevent famine-related deaths and malnutrition including micronutrient deficiencies"* and ensure *" the provision of a food basket that meets the assessed requirement and is nutritionally balanced and culturally acceptable"*.

Despite these agreements between the lead UN agencies, logistic and financial challenges mean that basic rations are limited, complementary food items are often not supplied, and rations may remain nutritionally inadequate. To illustrate the problem two rations, recommended in the WFP Food and Nutrition Handbook (2005), are analysed in table 5. Both show severe deficiencies of calcium and riboflavin. The maize based ration is also deficient in vitamin C.

[3] Expressed as reference nutrient intakes (RNI) for all nutrients except energy and copper.

[4] Note that NutVal 2006 and other software tools currently use different population requirement values but future versions are likely to incorporate the values given in table 4.

Table 5: Examples of typical general rations and micronutrient deficiencies

Maize-based		Rice-based	
MAIZE GRAIN, WHITE	400g	RICE, POLISHED	350g
BEANS, DRIED	60g	LENTILS	100g
VEGETABLE OIL	25g	VEGETABLE OIL	25g
CORN SOY BLEND	50g	CORN SOY BLEND	50g
SUGAR	15g	SUGAR	20g
IODISED SALT	5g	IODISED SALT	5g

Nutrient Adequacy (%)

Ration type	Energy	Protein	Fat	Calcium	Iron	Iodine	Vitamin A	Thia-mine	Ribo-flavin	Niacin	Vitamin C
	Kcal	g	g	mg	mg	µg	µg RE	mg	mg	mg	mg
Maize-based	99	116	112	45	101	201	95	229	92	126	88
Rice-based	100	117	77	38	97	201	97	116	50	226	110

Ration composition is taken from the WFP (2005) *Food and Nutrition Handbook*. Rome: WFP

The nutrient adequacy was calculated using the NutVal 2006 spreadsheet calculator.

Monitoring ration contents and dietary intakes

Even if a general food ration is correctly designed to meet nutrient requirements, the ration that is actually received and consumed by the population may differ for several reasons:

- The ration actually distributed on a particular distribution cycle might differ from the planned one for logistical reasons. For example, some items might be missing and be replaced (or not) by others.
- At the distribution point, problems in distribution procedures might mean that people do not receive the intended quantities of the planned ration.
- Food rations are often not entirely used for consumption but may be sold or exchanged for different purposes such as milling cereals, buying fresh foods and condiments to diversify the diet, buying essential non food items. This might be difficult to quantify with precision.
- The population might consume other foods in addition to the general ration.
- The size and structure of the beneficiary population may change due to in or out migration, births, or mortality, making the planning figures obsolete.

Good data on the functioning of a food aid system is essential for monitoring the risk of MDD. See figure 1. Assuming that the ration has been planned and assessed to be adequate, the three components of a good food aid monitoring system will usually include:

1 monitoring of the food aid logistics chain and distribution process

2 on-site distribution monitoring (OSDM) also sometimes called food basket monitoring and

3 post-distribution monitoring (PDM) at the household and market level.

All of these stages are necessary for adequate indirect assessment of the risk of micronutrient malnutrition.

The aim of OSDM is to compare the food actually received by families with the planned ration and to follow-up on any shortfall reported. Protocols for OSDM are laid out in Medecin Sans Frontieres (MSF) and UNHCR Guidelines. It is good practice for the agency doing the OSDM to be organisationally separate from that involved in food distribution to avoid any conflict of interest that might arise. Criteria for the interpretation of OSDM data have been laid down by UNHCR. According to the UNHCR guidelines, the cut-offs for acceptable distributions are < 90 per cent or >110 per cent of the planned kcal/person/day. While this is a useful criterion, it takes no account of differences that may be found in the distribution of different commodities and the impact on the micronutrient sufficiency of the ration.

Case example 1: Inadequate general rations associated with persistent angular stomatitis in refugees in Bangladesh: 2003

Since 1978, refugees from Northern Rakhine State, Myanmar, have been living in camps in the Cox's Bazar area of Bangladesh. Nutrition survey data was compiled in 2003 and showed that angular stomatitis, a clinical sign of ariboflavinosis, had been prevalent in children (6-59 months) since at least 1997. In 5 surveys conducted between 1997 and 2003 the prevalence of angular stomatitis varied from 7.0 to 12.6%, indicating chronic riboflavin deficiency.

Analysis of the on-site distribution survey (also called food basket monitoring) data showed that the general ration received during 2002 and the first half of 2003 contained an average of only 33% of the population requirement for riboflavin.

Despite the availability of this data no measures were taken at that time to improve the nutrient adequacy of the general ration. However, more recently micronutrient powders and other specialised food supplementation products have been piloted in these camps. See module 14 for more information on interventions for micronutrient malnutrition.

Report on Nutrition Survey and an Investigation of the Underlying Causes Of Malnutrition. Camps for Myanmar Refugees from Northern Rakhine State Cox's Bazar, Bangladesh, August 2003. UNHCR

Post Distribution Monitoring (PDM) should usually be conducted some time after the distribution (roughly 10-20 days after the distribution if the distributions are done on a monthly basis). The PDM looks at the use of the ration and the adequacy of the distribution system. In general, the scope of PDM is quite broad and includes other relevant food security information.

In many food aid operations the recipient populations are only partially dependent on food aid and may have access to a wide range of other commodities. While determining what these foods are may be relatively straightforward, gaining an accurate assessment of the quantities available and consumed often proves extremely difficult. The various food security methods that exist are very valuable for gaining in depth insight into household economies but are somewhat cumbersome to use to try and quantify the risk of micronutrient deficiencies.

Intra household distribution of food is another critical factor that may affect the risk of certain population groups developing deficiencies. Food distribution practices are often deeply entrenched in cultural norms and traditions.

RThe accurate measurement of dietary nutrient intake using weighed intakes, portion sizes or other methods is a challenging undertaking in any setting. Such approaches are usually inappropriate in refugee or emergency assessments although they have been used in research studies. The measurement of a diet diversity score or food variety score using food frequency questionnaires is, in contrast, a much simpler and more robust technique. The resulting scores have been shown to correlate with anthropometric status and haemoglobin concentration.

In these methods the survey subjects are asked whether they have consumed a specific food item or food group, typically within the last 24 hours or seven days. While it is not possible to calculate the actual quantities consumed, the diet diversity score or food variety score approach may be useful for understanding the sources of micronutrient-rich foods in the diet and for monitoring access to different foods over time.

When food aid is not intended to cover the full needs of the population, a significant amount of micronutrients might come from other sources of food. In this case, it might be difficult to find out what these other sources are and in what quantities they are being consumed.

When using indirect assessment for population subgroups, certain practical problems may occur. For example, although the RNI are given for different age and gender groups these may not always correspond to the groups that are being assessed.

A variety of software tools have been designed for calculating the nutrient content of food aid rations. The most well known include NutCalc, which was developed by EpiCentre for Action Contre le Faim, and NutVal, which was developed for UNHCR and WFP by the University College London Centre for International Health and Development.[5] Many other software products for the calculation of nutrient content exist but these tend not to be specialised for food aid operations.[6]

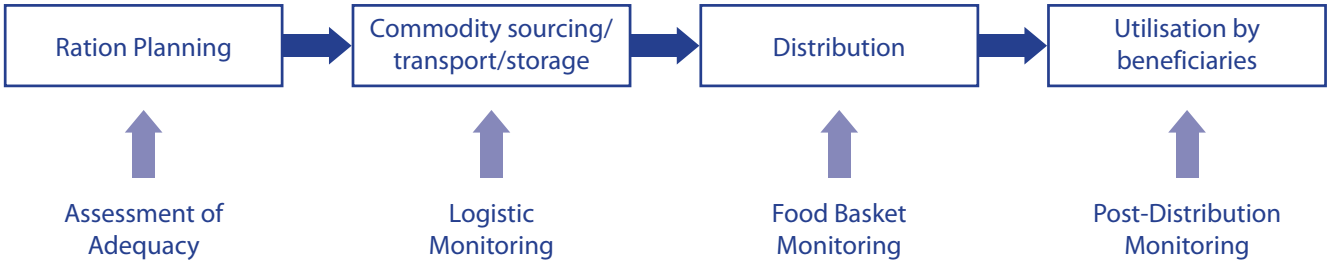
NutVal 2006 is currently recommended by WFP and UNHCR for use in planning and monitoring food aid rations.

Exercises included in part 3 of this module demonstrate the use of manual calculation and NutVal software for working out the micronutrient composition of food aid rations.

[5] NutVal can be downloaded free of charge from http://www.ucl.ac.uk/cihd/

[6] See INFOODS for a list of software products http://www.fao.org/infoods/software_en.stm

Figure 1: Monitoring points in a food aid system



Anecdotal reports indicate that ration monitoring by itself is a rather blunt tool for predicting the risk of MDD outbreaks, partly because a population's access to alternative diets may be underestimated.

In contrast, examples of the chronic persistence of seriously deficient diets together with direct evidence of clinical deficiency are also found. For example, in refugee camps in Bangladesh, food aid rations have been deficient in riboflavin for years and there is an associated high prevalence of angular stomatitis – a clear clinical indicator of riboflavin deficiency. Clearly, the evidence from the indirect assessment of the risk of micronutrient deficiencies may not always be effective in producing the necessary changes in food aid programmes.

Direct assessment: Measurement of micronutrient deficiencies in individuals and populations

There are two main approaches that can be used in direct assessment of micronutrient deficiencies:

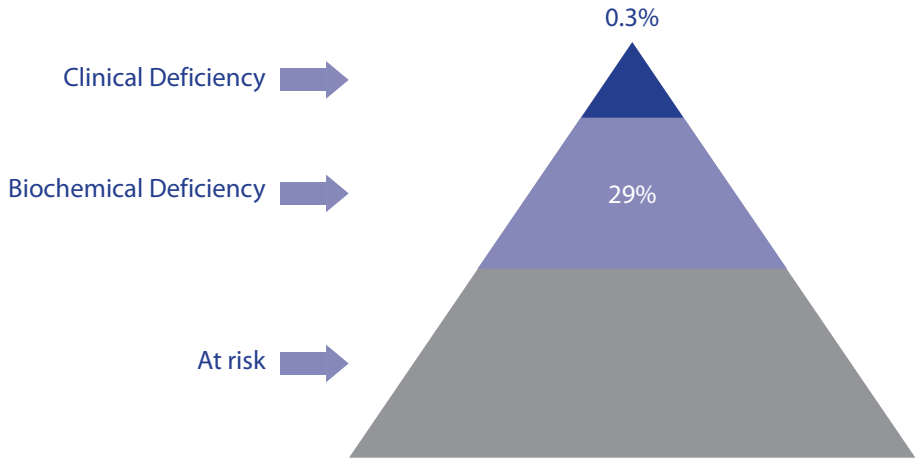
1. Clinical signs and symptoms
2. Biochemical testing

Each approach has potential advantages and disadvantages when considered for use in an emergency context.

Clinical signs and symptoms

Observation of clinical signs or the use of questionnaires to identify symptoms has the advantage of being non-invasive, usually low cost, and is often the most logistically feasible option in remote areas. Clinical signs continue to be used in nutrition surveys to try and obtain a prevalence measure of clinical deficiency. By definition, the use of clinical signs cannot tell us about the prevalence of sub-clinical deficiency and the detection of a clinical case usually represents the tip of the iceberg of the deficiency problem. See figure 2.

Figure 2: Schematic representation of how clinical and sub-clinical micronutrient deficiency is distributed in a population



The percentage of women affected by pellagra and niacin deficiency is shown as an example.
This data was collected during a survey in the Kuito area of central Angola in 2004.[7]

[7] Seal, AJ. et al. (2007) *Low and deficient niacin status and pellagra are endemic in postwar Angola.* Am J Clin Nutr 85: 218-224.

Box 1: Examples of the use of clinical signs in surveys

Angular stomatitis is a clinical sign of riboflavin deficiency. It has been measured in nutritional surveys of Bhutanese refugees living in Nepal camps for a number of years. A nutritional survey conducted in January 2007 found a prevalence of 1.0% (95% CI 0.4-2.3). The prevalence of this clinical sign had markedly decreased from about 40% in 2000. This may reflect improvements in the general ration due to the inclusion of blended food and other initiatives. However, the survey had been conducted during a different season to the previous one. This made interpretation difficult as the improvement may just reflect seasonal differences in food availability.
http://www.unscn.org/layout/modules/resources/files/NICS_No_13.pdf

Night blindness is a clinical sign of vitamin A deficiency. A survey conducted in the eight most vulnerable areas of Bahjang district, Nepal, in December 2006 measured night blindness in children and their mothers. The reported prevalence was 0.5% in children and 15.4% in mothers. The public health significance of this indicator should be assessed in children (preferably between 24-71 months). The prevalence measured indicates a mild public health problem in this situation (see Annex 3 of this module)
http://www.unscn.org/layout/modules/resources/files/NICS_No_13.pdf

An important distinction is between the use of clinical signs and symptoms. Clinical signs are pathological changes that can be observed by the surveyor or medical practitioner. The subject may or may not be aware of the presence of clinical signs. Symptoms are changes that are apparent to the patient or subject but may not always be observable by others. Therefore, in survey work clinical signs rather than symptoms are almost always used. The use of carer or self reported night blindness, as an indicator of vitamin A deficiency, is one notable exception.

While clinical signs are very useful they are, with a few exceptions, often quite non-specific. Goitre is a good example of a specific clinical sign of iodine deficiency but even then, goitre may actually result from iodine excess or some other disease process, rather than iodine deficiency. Angular stomatitis is often considered as a specific sign for riboflavin deficiency but in fact is associated with at least three nutrient deficiencies (riboflavin, vitamin B6 and zinc). Nonetheless, the sensitivity and specificity is adequate to make such signs extremely useful for inclusion in surveys.[8]

Clinical signs are often used in outbreak investigations such as of scurvy in Afghanistan and pellagra in Angola. Nutrition surveys quite frequently report the use of clinical signs in assessment of deficiencies. Recent examples include surveys of goitre in Ivory Coast, and Bitot's Spots for vitamin A deficiency in Darfur.

Training staff in correct diagnosis of clinical signs is sometimes challenging and the use of medically qualified staff is recommended whenever possible.

When conducting surveys of micronutrient deficiency diseases, a clear and simple case definition is essential and the ability of the survey staff to reliably identity cases should be assessed. For example, pellagra can be assessed using the case definition 'presence of bilateral, symmetrical dermatitis on one or more sun exposed areas of the skin'. Different degrees of vitamin A deficiency in young children can be assessed using the case definitions 'presence of night blindness' 'presence of Bitot's spots''presence of corneal xerosis, ulceration or keratomalacia', 'presence of corneal scars'.

Careful training is essential and where rare conditions are being surveyed it is advisable for the survey supervisor to revisit all suspected cases to confirm the diagnosis. It may be the case that an adequate case definition cannot be established with the use of clinical signs by themselves and cut-off values from biochemical testing may form an important part or the whole of the case definition.

Biochemical tests

Biochemical tests have the advantage of providing objective measures of micronutrient status. A classification of the different types of biochemical tests is given in box 2.

The collection of biological samples for testing often presents logistic, staff training, cold chain, and sometimes, acceptability challenges. Biochemical measurements are also not always as clear-cut, i.e. as sensitive and specific, as might be imagined. Individuals have a wide range of normal values and there are large differences between the average values of different healthy individuals. There also may be variations according to the time of day the sample is collected.

[8] Sensitivity is the ability of a test method to detect cases of a disease in people who do actually have the disease. Specificity is the ability of a test method to show a negative result in people without the disease.

Box 2: Types of biochemical tests for detecting nutritional deficiencies

1. Static measurements of nutrient under study in blood, urine, or other biological sample (e.g. serum retinol)
2. Measurement of a nutrient metabolite, (e.g. N-methylnicotinamide in urine as an indicator of Niacin status)
3. Biochemical functional test (e.g. enzyme activity in red blood cells for vitamins B1 and B2)
4. Presence of abnormal metabolites (e.g. homocysteine for folate deficiency)
5. Product of nutrient under study (e.g. haemoglobin concentration for iron status)
6. Load or saturation test (e.g. vitamin C in urine after consumption of a high dose tablet)
7. Other procedures (e.g. use of stable isotopes)

Adapted from: Sauberlich, H.E. (1999) *Laboratory Tests for the Assessment of Nutritional Status*. CRC Press

As with all assessment methods, care needs to be taken in interpreting results obtained at different times of the year. There may be normal fluctuations in micronutrient status due to the affects of the seasons on food availability and/or infections. For example, it has been shown that the vitamin A status of people in the Gambia varies depending on whether samples are collected during the wet or dry seasons.

Furthermore, different laboratories may produce results that do not agree well. Good quality assurance and quality control testing is essential and should always be considered when selecting a laboratory for sample testing.

We also need to be aware that a number of different biochemical tests may be available for the same micronutrient, and these may not necessarily give comparable answers. For example, iron status may be quantified by measuring a number of different components including serum ferritin, serum transferrin receptor, zinc protophorphyrin, and transferrin saturation. At the population level it may also be estimated from haemoglobin concentration. However, each of these measures is focused on a different part of the iron metabolic pathway so it should be no surprise that different estimates of deficiency may be obtained when using these different tests with the same samples. Again, standardisation of methodologies and cut-off values is essential to allow valid comparisons between surveys or studies.

Biochemical measurements might sometimes only give part of an answer. For example, low haemoglobin blood concentration indicates anaemia. However, anaemia might be related to iron deficiency or to infections, especially malaria or hookworm, which causes a reduction in haemoglobin blood concentration, or to inherited conditions such as sickle cell anaemia or thalassaemia.

Finally, for some of the micronutrients, published methods may prove very difficult to apply in field based surveys, e.g. because of contamination in trace element analysis or the requirement for extended sample collection time.

In conclusion, before embarking on an assessment involving biochemical testing it should be understood that the results obtained should not always be regarded as definitive, but they can provide an invaluable additional tool in reaching conclusions. Table 6 provides examples of recent studies where biochemical measurements have been taken. A summary of tests that may be considered for inclusion in surveys is included in **Annex 2**.

Operational organizations are, in general, becoming more aware of the importance of micronutrient malnutrition. For example, UNHCR has integrated haemoglobin measurement into routine nutrition surveys in a number of camps, particularly in Tanzania, Algeria and Kenya. Data from these periodic surveys is used for nutritional surveillance.

Challenge 1: Biochemical assessment in people with infections

When people have an infection, the body launches an acute phase response in which the levels of protein production change and the concentration of circulating nutrients in the blood is altered. This response may help the body in combating the infection and is a normal physiological response to inflammation. However, it does mean that if certain indicators of nutritional status are measured in a person with infection they will appear to have a worse nutritional status than they actually do. This applies in particular to serum retinol and ferritin, two popular indicators of vitamin A and iron status. Measurement of acute phase proteins, which are markers of inflammation, can allow for adjustment of the measured nutrient indicators, but there is not yet a widespread consensus on how adjustments should be applied.

Table 6: Recent examples of field studies using biochemical testing

Survey or Study	Location	Nutrient	Test
Kassim et al. (2010)[9]	Kenya – refugees from Somalia	Iodine	Urinary iodine excretion
Seal et al. (2006)[10]	Angola – post conflict resident population	Niacin	Urine excretion of N-methyl nicotinamide and 2-pyridone
Bennett and Coninx (2005)[11]	East Africa – prisoners	Vitamin C	Serum ascorbic acid
Seal et al. (2005)[12]	Africa – refugees from various countries	Vitamin A and iron	Serum retinol, Haemoglobin and sTfR
Kemmer et al. (2003)[13]	Thailand – refugees from Myanmar	Iron	Haemoglobin and zinc protoporphyrin
McGready (2003)[14]	Thailand – Karen refugees	Thiamine and vitamin A	ETKAC, breast milk retinol
Blanck et al. (2002)[15]	Nepal – refugees from Bhutan	Riboflavin	EGRAC

Before deciding to use biochemical sampling as a tool in nutritional surveys there are a number of important considerations to take into account. The points below do not comprise a manual for how-to-do-it but may help to indicate a few of the challenges and potential pitfalls.

- Employing the use of good training and technique, and following universal safety precautions helps to minimise the risk of cross-infection with pathogens such as HIV and Hepatitis B. Any potential benefits of conducting the survey need to be balanced against the risks to participants and staff. Survey participants need to be given full and honest information about the objectives and methods of the survey and informed consent must be obtained and documented.
- Selection of sampling method and equipment can greatly reduce the risk and discomfort for both parties. If at all possible, capillary blood collection should be used instead of venous sampling and the sample collected straight into a specialised tube with the appropriate anticoagulant or serum separator gel.
- Safety lancets with automatically self-retracting blades minimise the risk of needle stick injuries and makes reuse and cross-contamination impossible. If venous sampling is strictly necessary then vacuum loaded blood tubes can ease the collection process and a good quality, disposable, sharps collection box permits storage and transport of waste between survey sites.
- If surveys are being conducted at the household level then care must be taken not to contaminate any items with blood, remove any waste, and leave the house as it was found. While sticking plasters should be applied after any incisions it is good practice not to use 'child-friendly' plasters with pictures of animals or the like, as these may end up being popular and swappable items!
- Disposable or washable plastic cups should be used for urine collection and disposable plastic tubes for faecal samples. Medical plastic gloves for sample collectors often end up comprising the heaviest items in the survey supplies list and these and other items may need to be sourced from national or international suppliers a long way distant from the survey site. Good planning and use of a detailed inventory is essential!

[9] Kassim, IAR. et al. (2010) Excessive iodine intake during pregnancy in Somali refugees Maternal and Child Nutrition DOI: 10.1111/j.1740-8709.2010.00259.

[10] Seal AJ. et al. (2007) *Low and deficient niacin status and pellagra are endemic in postwar Angola.* Am J Clin Nutr. 85 (1): 218-24

[11] Bennett, M. & Coninx, R. (2005) *The mystery of the wooden leg: vitamin C deficiency in East African prisons*. Trop.Doct. 35: 81-84.

[12] Seal A.J. et al (2005) *Iron and vitamin A deficiency in long-term African refugees*. J Nutr. 135: 808-13

[13] Kemmer T.M. et al (2003) *Iron deficiency is unacceptably high in refugee children from Burma*. J Nutr. 133: 4143-9

[14] McGready, R. et al (2003) *Delayed visual maturation in Karen refugee infants*. Ann.Trop.Paediatr. 23: 193-204.

[15] Blanck, H. M. t al (2002) *Angular stomatitis and riboflavin status among adolescent Bhutanese refugees living in southeastern Nepal*. Am.J.Clin.Nutr. 76: 430-435.

- Sample preservation before and during transport/or analysis is often challenging. Supplies of ice or dry ice are usually required but may be difficult to source. Fridges and freezers may work intermittently and extra fuel may need to be purchased, or solar power laid on to keep them going constantly without interruption during the duration of the survey. The use of dried blood spots, where a spot of blood is dried onto filter paper and then transported in a normal envelope provides a, potentially, much simpler solution for sample storage. But caution is advised unless studies have already been performed to show that the results obtained from samples stored in this way are comparable with results from liquid samples.
- Finally, formal ethical clearance may be required from national and/or international bodies and obtaining the necessary paperwork may be a time consuming process.

Selection of appropriate population groups and methods for surveys of micronutrient malnutrition

In some situations the careful documentation of individual case studies may be powerful and sufficient evidence to advocate for intervention, especially where the condition is rare, such as for scurvy or pellagra. However, quantification at the population level is often required.

In deciding on a method for assessment of a suspected micronutrient problem it is critical to select the appropriate population group for study. Table 6 gives guidance on which groups to select to gain the most useful indicator. This depends on the relative susceptibility of different age and gender groups and the availability of assessment methods.

The sample size required for micronutrient surveys is typically very large where clinical signs are used but a lot smaller where biochemical measurements are taken. This reflects the relative rarity of overt clinical cases compared to the more prevalent sub-clinical biochemical deficiency that is usually encountered.

Sampling methods may utilise a number of different techniques depending on the target population but cluster sampling using probability proportional to size will frequently be appropriate and may allow integration with a standard nutrition survey (see module 7 for more details about nutrition surveys). However, it is important to note that the population subgroup and the required sample size will usually be different than that required for a standard anthropometric nutrition survey.

Surveillance systems are an alternative to conducting surveys and if micronutrient deficiencies, assessed using either biochemical tests or clinical signs, are effectively integrated into a health information system, monitoring may be relatively low cost and reliable.

Conclusions

Tools for assessing micronutrient status in emergencies are available for both indirect and direct assessment approaches. However, there are a number of challenges that limit their implementation in the field and careful selection and use is required.

For indirect assessment, it is important to try and gain an understanding of the total dietary intake of micronutrients. For effective monitoring of the contribution provided by food aid it is essential to assess the planned ration, the delivery of the planned ration through the logistics chain, receipt of the ration through onsite distribution monitoring, and the use of the ration through post-distribution monitoring.

Direct assessment of micronutrient malnutrition depends on looking for clinical signs of deficiencies or taking a blood or urine sample for biochemical analysis.

Staff can be trained to recognise the common clinical signs of micronutrient deficiency disease by the use of photo-cards. This approach is relatively fast and has a low cost. However, clinical signs are not always specific.

Further improvements in field friendly techniques for the biochemical assessment of deficiencies are needed. With the exception of the HemoCue photometer, used for the measurement of haemoglobin in a finger prick blood sample, collection of biological samples for the analysis of micronutrients remains challenging. Whilst some techniques have been developed using dried blood spots, direct collection and storage of liquid serum and urine remain a more reliable method of sample collection. More work on sample collection and storage methods is required to make field surveys easier to conduct in remote locations.

Information on actual or potential micronutrient malnutrition should always be crosschecked against other available data to try and obtain the most accurate picture of what is happening.

Micronutrient malnutrition remains a major public health issue that is far from being eliminated.

Annex 1: Recommended nutrient intakes by population group

Source: WHO/FAO (2004): Vitamin and mineral requirements in human nutrition, Second edition: WHO: Geneva

Recommended nutrient intakes[a] – minerals

Group	Calcium[b] (mg/day)	Selenium (mg/day)	Magnesium (mg/day)	Zinc[c] (mg/day)		
				High bio-availability	Moderate bio-availability	Low bio-availability
Infants	300[d]		26[d]			
0-6 months	400[g]	6	36[h]	1.1[d]	2.8	6.6
7-12 months	400	10	54	0.8[d] 2.5[j]	4.1	8.4
Children						
1-3 years	500	17	60	2.4	4.1	8.3
4-6 years	600	22	76	2.9	4.8	9.6
7-9 years	700	21	100	3.3	5.6	11.2
Adolescents						
Females 10-18 years	1300[k]	26	220	4.3	7.2	14.4
Males 10-18 years	1300[k]	32	230	5.1	8.6	17.1
Adults						
Females 19-50 years (premenopausal)	1000	26	220	3.0	4.9	9.8
Females 51-65 years (menopausal)	1300	26	220	3.0	4.9	9.8
Males 19-65 years	1000	34	260	4.2	7.0	14.0
Elderly						
Females 65+ years	1300	25	190	3.0	4.9	9.8
Males 65+ years	1300	33	224	4.2	7.0	14.0
Pregnant women						
First trimester	[m]	[m]	220	3.4	5.5	11.0
Second trimester	[m]	28	220	4.2	7.0	14.0
Third trimester	1200	30	220	6.0	10.0	20.0
Lactating women						
0-3 months	1000	35	270	5.8	9.5	19.0
3-6 months	1000	35	270	5.3	8.8	17.5
7-12 months	1000	42	270	4.3	7.2	14.4

[a] Recommended nutrient intake (RNI) is the daily intake which meets the nutrient requirements of almost all (97.5%) apparently healthy individuals in an age- and sex-specific population.

[b] For details, see chapter 4 in WHO/FAO (2004): Vitamin and mineral requirements in human nutrition, Second edition: WHO: Geneva.

[c] For details, see chapter 12 in WHO/FAO (2004): Vitamin and mineral requirements in human nutrition, Second edition: WHO: Geneva.

[d] Breastfed.

[e] Neonatal iron stores are sufficient to meet the iron requirement for the first 6 months in full-term infants. Premature infants and low birth weight infants require additional iron.

[f] Recommendation for the age group 0-4.9 years.

[g] Cow milk-fed.

[h] Formula-fed.

Iron (mg/day)				
15% Bioavailability	12% Bioavailability	10% Bioavailability	5% Bioavailability	Iodine (µg/day)
[e]	[e]	[e]	[e]	90[f]
6.2[i]	7.7[i]	9.3[i]	18.6[i]	90[f]
3.9	4.8	5.8	11.6	90[f]
4.2	5.3	6.3	12.6	90[f]
5.9	7.4	8.9	17.8	120 (6-12yrs)
9.3 (11-14yrs)[l]	11.7 (11-14yrs)[l]	14.0 (11-14yrs)[l]	28.0 (11-14yrs)[l]	150 (13-18yrs)
21.8 (11-14yrs)	27.7 (11-14yrs)	32.7 (11-14yrs)	65.4 (11-14yrs)	
20.7 (15-17yrs)	25.8 (15-17yrs)	31.0 (15-17yrs)	62.0 (15-17yrs)	
9.7 (11-14yrs)	12.2 (11-14yrs)	14.6 (11-14yrs)	29.2 (11-14yrs)	150 (13-18yrs)
12.5 (15-17yrs)	15.7 (15-17yrs)	18.8 (15-17yrs)	37.6 (15-17yrs)	
19.6	24.5	29.4	58.8	150
7.5	9.4	11.3	22.6	150
9.1	11.4	13.7	27.4	150
7.5	9.4	11.3	22.6	150
9.1	11.4	13.7	27.4	150
[n]	[n]	[n]	[n]	200
[n]	[n]	[n]	[n]	200
[n]	[n]	[n]	[n]	200
10.0	12.5	15.0	30.0	200
10.0	12.5	15.0	30.0	200
10.0	12.5	15.0	30.0	200

[i] Bioavailability of dietary iron during this period varies greatly.

[j] Not applicable to infants exclusively breastfed.

[k] Particularly during the growth spurt.

[l] Pre-menarche.

[m] Not specified.

[n] It is recommended that iron supplements in tablet form be given to all pregnant women because of the difficulties in correctly assessing iron status in pregnancy.

Recommended nutrient intakes[a] – water and fat-soluble vitamins

Group	Water-soluble vitamins					
	Vitamin C[b] (mg/day)	Thiamine (mg/day)	Riboflavin (mg/day)	Niacin[c] (mg NE/day)	Vitamin B6 (mg/day)	Pantothenate (mg/day)
Infants						
0-6 months	25	0.2	0.3	2[i]	0.1	1.7
7-12 months	30	0.3	0.4	4	0.3	1.8
Children						
1-3 years	30	0.5	0.5	6	0.5	2.0
4-6 years	30	0.6	0.6	8	0.6	3.0
7-9 years	35	0.9	0.9	12	1.0	4.0
Adolescents						
Females 10-18 years	40	1.1	1.0	16	1.2	5.0
Males 10-18 years	40	1.2	1.3	16	1.3	5.0
Adults						
Females 19-50 years (premenopausal)	45	1.1	1.1	14	1.3	5.0
Females 51-65 years (menopausal)	45	1.1	1.1	14	1.5	5.0
Males 19-65 years	45	1.2	1.3	16	1.3 (19-50yrs) 1.7 (50+yrs)	5.0
Elderly						
Females 65+years	45	1.1	1.1	14	1.5	5.0
Males 65+years	45	1.2	1.3	16	1.7	5.0
Pregnant women	55	1.4	1.4	18	1.9	6.0
Lactating women	70	1.5	1.6	17	2.0	7.0

[a] Recommended nutrient intake (RNI) is the daily intake which meets the nutrient requirements of almost all (97.5%) apparently healthy individuals in an age- and sex-specific population.

[b] For details, see chapter 7 in WHO/FAO (2004): Vitamin and mineral requirements in human nutrition, Second edition: WHO: Geneva.

[c] NE = Niacin equivalents.

[d] DFE = Dietary folate equivalents; µg of DFE provided = [µg of food folate + (1.7 x µg of synthetic folic acid)].

[e] Vitamin A values are "recommended safe intakes" instead of RNIs. For details, see chapter 2 in WHO/FAO (2004): Vitamin and mineral requirements in human nutrition, Second edition: WHO: Geneva.

[f] Recommended safe intakes as mg retinol equivalent (RE)/day; conversion factors are as follows:
1µg retinol = 1 RE
1µg b-carotene = 0.167µg RE
1µg other provitamin A carotenoids = 0.084µg RE.

Water-soluble vitamins			Fat-soluble vitamins			
Biotin (µg/day)	Vitamin B12 (µg/day)	Folate[d] (µg DFE/day)	Vitamin A[e,f] (µg RE/day)	Vitamin D (µg/day)	Vitamin E[g] (mg alpha-TE/day)	Vitamin K[h] (µg/day)
5	0.4	80	375	5	2.7[j]	5[k]
6	0.7	80	400	5	2.7[j]	10
8	0.9	150	400	5	5.0[j]	15
12	1.2	200	450	5	5.0[j]	20
20	1.8	300	500	5	7.0[j]	25
25	2.4	400	600	5	7.5	35-55
25	2.4	400	600	5	10.0	35-55
30	2.4	400	500	5	7.5	55
30	2.4	400	500	10	7.5	55
30	2.4	400	600	5 (19-50yrs) 10 (51-65yrs)	10.0	65
	2.4	400	600	15	7.5	55
[l]	2.4	400	600	15	10.0	65
30	2.6	600	800	5	[j]	55
35	2.8	500	850	5	[j]	55

[g] Data were not strong enough to formulate recommendations. The figures in the table therefore represent the best estimate of requirements.

[h] For details, see chapter 6 in WHO/FAO (2004): Vitamin and mineral requirements in human nutrition, Second edition: WHO: Geneva.

[i] Preformed niacin.

[j] For details, see chapter 5 in WHO/FAO (2004): Vitamin and mineral requirements in human nutrition, Second edition: WHO: Geneva.

[k] This intake cannot be met by infants who are exclusively breastfed. To prevent bleeding due to vitamin K deficiency, all breast-fed infants should receive vitamin K supplementation at birth according to nationally approved guidelines.

[l] Not specified.

Annex 2: Biochemical tests for anaemia and selected nutrient deficiencies

	Available Options	Recommended	Rational
Anaemia	1 Haemoglobin (Hb) 2 Haematocrit	Haemoglobin	Haemoglobin concentration is a direct measure of anaemia. Using a field photometer such as the Hemocue, measures are quick, easy, and can be carried out at household level during surveys.
Iron	1 Serum tranferrin receptors (sTfR) 2 Ferritin 3 Serum iron 4 Transferrin saturation 5 Erythrocyte protoporphyrin	sTfR	sTfR is affected little by concurrent infections and is a widely used measure of iron deficiency. Measurements can be made on serum samples prepared from a finger stick capillary blood sample. If ferritin is used the values obtained have to be controlled for inflammation status.
Iodine	1 Urinary iodine 2 Neonatal TSH 3 Thyroglobulin	Urinary Iodine	Single samples of urine can be easily collected from school aged children or adult women. Samples are stable and it is not essential to freeze them during transport. Calculation of the median urinary excretion is widely accepted as a valid method of measuring population status.
Vitamin A (Retinol)	1 Serum retinol 2 Retinol binding protein 3 Relative dose response tests	Serum retinol	Serum retinol concentration is a good indicator of vitamin A status in populations Measurements can be made on serum samples prepared from a finger stick capillary blood sample. Samples from the same finger stick can be used for both iron and vitamin A measurements.
Vitamin B1 (Thiamine)	1 Erythrocyte Transketolase Activity Coefficient (ETKAC) 2 Blood concentration of thiamine 3 Urine excretion	All methods have disadvantages but ETKAC is generally regarded as the most valid measure of status.	The ETKAC assay measures the activity of an enzyme that is dependent on thiamine. A well accepted functional measurement but requires the collection, centrifugation and freezing of venous blood samples.
Vitamin B2 (Riboflavin)	1 Erythrocyte Glutathione Reductase Activity Coefficient (EGRAC) 2 Blood concentration of riboflavin	Both methods have disadvantages but have been used successfully in field studies.	The EGRAC assay measures the activity of an enzyme that is dependent on riboflavin. A well accepted functional measurement but requires the collection, centrifugation and freezing of venous blood samples.
Vitamin B3 (Niacin)	1 Urinary excretion of metabolites (1-methyl nicotinamide and 1-methyl-2-Pyridone-5-carboxamide).	Urinary excretion	The excreted metabolites are stable during storage, samples are easily collected and the method has been successfully used in field surveys.
Vitamin C	1 Serum/plasma concentration 2 Leukocyte concentration 3 Urine excretion	Serum concentration	Although storage and transport of serum samples requires freezing and may be problematic, serum vitamin C is an easier measure and requires lower sample volume than the isolation of white blood cells. Urine excretion only reflects recent intake and more research is required to assess how useful it is in population surveys.

For a consideration of the sample sizes required for different assessment methods see Annex 3.

Annex 3: Public health cut-offs for indicators of micronutrient deficiencies and example sample sizes[16]

Micronutrient Deficiency Indicator	Recommended Age Group for Prevalence Surveys	Definition of a Public Health Problem		Prevalence to detect	Precision	Sample size
		Severity	Prevalence (%)			
Vitamin A Deficiency[17]						
Night Blindness (XN)[18]	24-71 months	Mild	> 0 - < 1	–	–	–
		Moderate	≥ 1 - < 5	1.00	0.500	2,275
		Severe	≥ 5	5.00	2.500	438
Bitots spots (X1B)	6-71 months	Not specified	> 0.5	0.50	0.250	4,559
Corneal Xerosis/ulceration/ keratomalacia (X2, X3A, X3B)	6-71 months	Not specified	> 0.01	0.01	0.005	153,650
Corneal scars (XS)	6-71 months	Not specified	> 0.05	0.05	0.025	30,718
Breast milk retinol (≤ 1.05 (mol/L)	Mothers	Mild	< 10	–	–	–
		Moderate	≥ 10 - < 25	10.00	5.000	208
		Severe	≥ 25	25.00	7.500	221
Serum retinol (≤ 0.7 (mol/L)	6-71 months	Mild	≥ 2 - < 10	2.00	1.000	1,128
		Moderate	≥10 - < 20	10.00	5.000	208
		Severe	≥ 20	20.00	7.500	164
Iodine Deficiency[19]						
Goitre (visible + palpable)	School-age children	Mild	5.0 -19.9	5.00	2.500	438
		Moderate	20.0-29.9	20.00	7.500	164
		Severe	≥ 30.0	30.00	10.000	121
Median urinary iodine (µg/l)	School-age children	Adequate	100-199[20]	N/A[21]	N/A	≥ 40
		Mild	50-99	N/A	N/A	≥ 40
		Moderate	20-49	N/A	N/A	≥ 40
		Severe	< 20	N/A	N/A	≥ 40

[16] Calculations were performed with EpiInfo 6.04 and are based on a population size of 500,000 and a design effect of 1.5 for cluster surveys

[17] *'Indicators for Assessing Vitamin A Deficiency and their Application in Monitoring and Evaluating Intervention Programmes'* p.7 (1996) World Health Organisation, Geneva WHO/NUT/96.10

[18] The letter codes beginning in X, XN, X1B etc. are shorthand for the different types of xerophthalmia

[19] *'Assessment of iodine deficiency disorders and monitoring their elimination. A guide for programme mangers.'* (2007) 3rd Ed., Chapter 4, WHO/UNICEF/ICCIDD

[20] Figures given here are for the concentration of iodine in urine, not the prevalence.

[21] N/A – Not applicable

Public health cut-offs for indicators of micronutrient deficiencies and example sample sizes (continued)

Micronutrient Deficiency Indicator	Recommended Age Group for Prevalence Surveys	Definition of a Public Health Problem		Prevalence to detect	Precision	Sample size
		Severity	Prevalence (%)			
Iron Deficiency[22]						
Anaemia (Non-pregnant women haemoglobin <12.0g/dl; children 6-59 months <11.0g/dl)[23]	Women, Children	Low Medium High	5-20 20-40 ≥ 40	5.0 20.0 40.0	2.5 7.5 10.0	438 164 139
Beriberi[24]						
Clinical Signs	Whole population	Mild Moderate Severe	≥ 1 case & < 1% 1-4 ≥ 5	– 1.0 5.0	– 0.5 2.5	– 2,275 438
Thiamine pyrophosphate effect (TPPE) ≥ 25%	Whole population	Mild Moderate Severe	5-19 20-49 ≥ 50	5.0 20.0 50.0	2.5 7.5 12.0	438 164 101
Urinary thiamine per g creatinine (Age group specific cut-offs)	Whole population	Mild Moderate Severe	5-19 20-49 ≥ 50	5.0 20.0 50.0	2.5 7.5 12.0	438 164 101
Breast milk thiamine (< 50 (g/L)	Lactating women	Mild Moderate Severe	5-19 20-49 ≥ 50	5.0 20.0 50.0	2.5 7.5 12.0	438 164 101
Dietary intake (< 0.33mg/1000 kcal)	Whole population	Mild Moderate Severe	5-19 20-49 ≥ 50	5.0 20.0 50.0	2.5 7.5 12.0	438 164 101
Infant mortality	Infants 2-5 months	Mild Moderate Severe	No increase in rates Slight peak in rates Marked peak in rates	– – –	– – –	– – –

[22] Classification proposed in: *'The Management of Nutrition in Major Emergencies'* (2000) World Health Organisation, Geneva

[23] Cut-offs are given for < 1000m and may need to be adjusted according to age, sex and altitude

[24] Criteria proposed in: *'Thiamine Deficiency and its Prevention and Control in Major Emergencies'* p.14 (1999) WHO/UNHCR, Geneva WHO/NHD/99.13

Public health cut-offs for indicators of micronutrient deficiencies and example sample sizes (continued)

Micronutrient Deficiency Indicator	Recommended Age Group for Prevalence Surveys	Definition of a Public Health Problem		Prevalence to detect	Precision	Sample size
		Severity	Prevalence (%)			
Pellagra[25]						
Clinical Signs (Dermatitis) in surveyed age group	Whole population or women >15 years	Mild Moderate Severe	≥ 1 case & < 1% 1-4 ≥ 5	– 1.0 5.0	– 0.5 2.5	– 2,275 438
Urinary N-methyl nicotinamide < 0.5mg/g creatinine[26, 27]	Whole population or women >15 years	Mild Moderate Severe	5-19 20-49 ≥ 50	5.0 20.0 50.0	2.5 7.5 12.0	438 164 101
Dietary intake of niacin equivalents <5 mg/day	Whole population or women >15 years	Mild Moderate Severe	5-19 20-49 ≥ 50	5.0 20.0 50.0	2.5 7.5 12.0	438 164 101
Scurvy[28]						
Clinical signs	Whole population	Mild Moderate Severe	≥ 1 case & < 1% 1-4 ≥ 5	– 1.0 5.0	– 0.5 2.5	– 2,275 438
Deficient serum ascorbic acid (< 0.2mg/100ml)	Whole population	Mild Moderate Severe	10-29 30-49 ≥ 50	10.0 30.0 50.0	5.0 10.0 12.0	208 121 101
Low serum ascorbic acid (< 0.3mg/100ml)	Whole population	Mild Moderate Severe	30-49 50-69 ≥ 70	30.0 50.0 70.0	10.0 12.0 15.0	121 101 54

[25] Provisional criteria suggested in *'Pellagra and its Prevention and Control in Major Emergencies'* WHO/UNHCR, 2000, WHO/NHD/00.10 and 'Management of Nutrition in Major Emergencies', World Health Organisation, Geneva, 2000

[26] Although the use of the urinary ratio of 2-pyridone:N-methyl nicotinamide is provisionally recommended in WHO publications, subsequent research has demonstrated that when urine is collected at a single time point, such as during a survey, the metabolite ratio is not a stable indicator of nutritional status.

[27] Recent survey work from an area of Angola where pellagra is endemic has suggested that this cut-off needs to be revised upwards to 1.6 mg/g creatinine, and that the measurement of the 2-pyridone metabolite provides is a more reliable analytical measure. (Seal et al. (2007) *'Low and deficient niacin status and pellagra are endemic in post war Angola'* Am J Clin Nutr 85, 218-224)

[28] Provisional criteria suggested in *'Scurvy and its Prevention and Control in Major Emergencies'* p.9 (1999) World Health Organisation/UNHCR WHO/NHD/99.11