4.
ESSENTIAL NUTRIENTS IN DRINKING WATER

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I. INTRODUCTION

Most of the inorganic chemicals in drinking water are naturally occurring. They are acquired by the contact of water with rocks and soil and the effects of the geological setting, including climate (1-4). However, the chemical composition of drinking water also depends on the contaminating effects of industry, human settlements, agricultural activities and water treatment and distribution (1-4). Depending on water quality at the source, filtration, coagulation, and addition of chemicals to adjust pH and/or control corrosion treatments are employed (1-5). In addition, chlorination or iodination may be used for disinfection and fluoridation for the prevention of dental caries (6-8). Leaching of minerals from metal components used in water treatment plants and plumbing materials occurs when pH and hardness of water are not adjusted. Some of the main sources of dissolved metals include: for Cu- copper or brass plumbing system; Fe- cast iron, steel, and galvanised plumbing system; Zn- zinc galvanised pipes; Ni- chromium-nickel stainless plumbing system; Pb- derived from tin-lead or lead solder; and for Cd- as an impurity in zinc galvanised pipes or cadmium containing solders (1-4,9). Recently, fortification of drinking water has been used in the prevention of iron deficiency in children (10) and to provide iodine in select populations (11).

II. DEFINITION OF NUTRITIONAL REQUIREMENTS AND RECOMMENDATIONS

Experts from many countries and international organisations have defined nutritional needs and recommendations. The requirement of a nutrient, as defined by the World Health Organization, Food and Agriculture Organization of the United Nations and the International Atomic Energy Agency (WHO/FAO/IAEA) Expert Consultation on Trace Elements in Human Nutrition and Health, is “the lowest continuing level of nutrient intake that, at a specified efficiency of utilisation, will maintain the defined level of nutriture in the individual” (12). Basal requirement is the “intake needed to prevent pathologically relevant and clinically detectable signs of impaired function attributable to inadequacy of the nutrient”. However, the basal requirement does not account for the needs to maintain nutrient reserves in the body or consider the amount sufficient to ensure that absorption and retention were not operating at maximum capacity. Therefore, the value needed to fulfill the basal requirement plus these additional needs to maintain a level of tissue storage or other reserves constitutes the normative requirement (12).

However, how important reserves are is an open question. The criterion utilised to define nutrient inadequacy may differ for individuals at different life stage. On the other hand, the knowledge of the criteria used to define nutrient inadequacy is important to integrate and/or compare requirements obtained from different sources of evidence.

Several methods have been utilised to estimate requirements and each has particular strengths and weaknesses. Nutrient requirements can be calculated by using metabolic balance studies at different levels of intake, factorial modelling, in which the amount of the nutrient needed to replace utilisation and losses is calculated, depletion/repletion studies, and/or epidemiological evidence (12-17). Balance studies and factorial analysis calculations can be biased since individuals can adapt to the level of nutrient intake by modifying absorption and/or losses. As previously mentioned, micromineral requirements can be studied by experimental diets with different micromineral intakes, thus determining the minimal nutrient intake that prevents the development of biochemical abnormalities or functions. However, these experimental diets may also have modifications in other nutrients that could affect absorption of the studied nutrient or influence the biochemical or physiological parameters employed in the assessment of its status. In addition, the biochemical parameters may not be sufficiently sensitive and/or specific in detecting marginal nutrient status. Another method is to calculate the requirements based on epidemiological studies of nutrient status carried out in healthy populations with different nutrient intake profiles (12-15,17).

Dietary reference intakes are provided to promote optimal health by avoiding consequences of nutrient deficiency and excess. However, for some nutrients there is limited information to scientifically support the nutritional needs across age ranges, gender and physiological states.

The Institute of Medicine of the US National Academy of Sciences (IOM) has developed dietary reference intakes (DRI) that include the Estimated Average Requirement (EAR), Recommended Dietary Allowance (RDA), Adequate Intake (AI) and Tolerable Upper Intake Level (UL) (13). The EAR, RDA, and AI values represent the amount of the nutrient to be supplied by foods from a diet similar to those consumed in Canada and the United States. EAR is the daily intake of a nutrient that is estimated to meet the requirement of 50% of apparently healthy individuals of a given sex and age. The RDA is the average daily intake level that is sufficient to meet the nutrient requirement of 97.5% of the population of apparently healthy persons of a given sex and age. This value is intended to be used as a goal for daily intake by all individuals to be reached as an average over a given time; usually weeks or months. When there is insufficient information available to calculate an EAR, an AI value based on experimentally derived intake levels or approximations of customary mean nutrient intakes by group or groups of healthy subjects, is used instead of the traditional RDA. The UL is the highest level of daily nutrient intake that is likely to pose no risk of adverse health effect for almost all individuals in a specified sex and age group. The development of a UL for a nutrient requires: 1. Hazard identification (identification of all known adverse effects associated with the nutrient). 2. Analysis of dose response studies to identify the lowest no observed adverse effect level (NOAEL) based on all identified hazards, and 3. Application of an uncertainty factor, that compensates for extrapolation from the observed to the general population (13,18).

WHO/FAO/IAEA has established safe levels of population mean intakes that would suffice to ensure a low prevalence of individuals at risk of either inadequate or excessive intakes (12). The lower limit of the population mean intake is “the lowest mean intake at which the population risks of depletion remain acceptable when judged by normative criteria”, while the upper limit is “the maximum population mean intake at which the risks of toxicity remain tolerable”. Between these limits the risk of inadequacy or excess is acceptably low. In addition, the lower limit of the population mean intake was established based on the basal requirement criteria. Below this limit there is a gradual increase on the prevalence of individuals expected to show demonstrable signs of functional impairment. Recently FAO/WHO defined recommended nutrient intake (RNI) as "the daily intake, which meets the nutrient requirements of almost all (97.5 percent) apparently healthy individuals in an age and sex-specific population group" (19). This definition is equivalent to that of RDA. RNI considers the nutrient intake from food including water.

In 1993 the Scientific Committee for Food of the European Commission (15) defined the Lowest Threshold Intake (LTI) as "the intake below which nearly all individuals will be unable to maintain metabolic integrity according to the criterion chosen for each nutrient". The Average Requirement (AR) is the intake that covers 50% of requirements for the group according to criteria chosen. The Population Reference Intake (PRI) is "the intake that will meet the needs of nearly all healthy people in a group" (97.5%).

An interesting modification in the approach to define the regulatory framework for assessing risks for essential trace elements is the concept of including the risk of both deficiency and excess in the model. In 2001 the International Programme on Chemical Safety (IPCS) proposed a methodology to establish a homeostatic model for determining the Adequate Range of Oral Intake (AROI) of essential trace elements (20). This model includes weighing the evidence of hazards linked to deficit with that related to excess and selecting relevant endpoints of deficiency and toxicity at different ages, gender and conditions. In addition, the probability of risk and the severity of various effects are quantified and those that are critical to determine cut-off points for deficiency and toxicity are selected. The AROI is established by balancing endpoints of comparable health significance on the deficiency and excessive intake sides.

III. WHAT ARE THE IMPORTANT DIETARY MINERALS AND ELECTROLYTES IN THE DIET AND POTENTIALLY IN WATER THAT ARE ESSENTIAL FOR NUTRITION AND WELLBEING?

Calcium, Na, K, Cl, Mg, Fe, Zn, Cu, Cr, I, Co, Mo and Se are unequivocally essential for human health; although not commonly realised drinking water provides some of these elements. A second group of elements that have some beneficial health effects, include F in the prevention of dental caries and B, Mn, Ni, Si and Va, that may be considered essential for humans based on emerging information. The third group is composed of the potentially toxic elements Pb, Cd, Hg, As, Al, Li and Sn (1,3,12,21).

The relative of contribution of water to total dietary intake of selected trace elements and electrolytes is between 1 and 20%. The micronutrients with the largest proportion of intake from drinking water relative to that provided by food are calcium and magnesium. For these elements water may provide up to 20% of the required total daily intake. For the majority of other elements drinking water provides less than 5 % of total intake (1,3,12,21). An exception may be the high contribution of fluoride and arsenic in in certain geographic regions (eg. deep-water wells, water passing through volcanic run-offs, desert sources) (1,3,12,21).

It is customarily assumed that the intake of essential elements is primarily covered by foods, thus minimum desirable levels in drinking water are not considered necessary. Yet for populations that have low consumption of animal flesh foods the intake of Fe, Zn and Cu may in fact be marginal or lower than needed, in which case sufficiency may depend on the metal contamination of foods and water. Some epidemiological evidence suggests that water hardness is associated with beneficial effects for human health. The ample epidemiological evidence, which is supported by case control studies, demonstrates an inverse relationship between drinking water hardness and cardiovascular or cerebrovascular diseases (3). However, available information is insufficient to conclude that the relationship is causal.

IV. WHAT ARE THE RDAS FOR MINERALS AND ELECTROLYTES AND HOW ARE THEY DETERMINED?

We will review and analyse how RDAs for iron, zinc, copper, iodine, calcium, phosphorus, magnesium, fluoride, sodium, potassium and chloride were established. AIs are provided instead of RDAs when there is insufficient scientific information to estimate requirements. The nutrient intake of breast-fed infants is frequently utilised to set AIs for infants from 0 to 6 months of age; for infants 7 to 12 months of age the average intake from human milk plus the additional intake provided by complementary foods is utilised (12,14,15). Determining values for requirements during pregnancy usually includes an estimate of the quantity of the element required by the foetus and other products of pregnancy, and required for body changes that occur during this stage of the life cycle (i.e. expansion of blood volume) (12,14,15,19). Requirements for lactation include the need to replace the amount of the nutrient lost daily in human milk (12,14,15,19). The dietary reference intakes and WHO standard for drinking water for iron, zinc, copper, iodine, calcium, phosphorus, magnesium, fluoride, sodium, potassium and chloride are summarised in tables 1 to 9.

1. Iron

Iron participates in numerous processes necessary for normal body functions: oxygen transport, oxidative phoshorylation, metabolism of neurotransmitters, and DNA synthesis require iron (22). While the main effect of iron deficiency is anaemia, other manifestations of iron deficiency include impaired mental and motor development and altered behaviour. Other symptoms that may be observed with iron deficiency are delayed nerve conduction affecting the auditory and visual systems, decreased capacity for physical work, increased spontaneous motor activity, impaired cell-mediated immunity and bactericidal capacity of neutrophils, impaired thermoregulation, functional and histologic abnormalities of the gastrointestinal tract, defective mobilisation of liver vitamin A, increased risk of premature birth, low birth-weight and growth retardation, increased perinatal morbidity and reduced iron transfer to the foetus (23-26). Iron deficiency is the single most common nutritional disorder worldwide and the main cause of anaemia in infancy, childhood and pregnancy (27). It is prevalent in most of the developing world and it is probably the only significant nutritional deficiency found in industrialised countries. The main cause of iron deficit is a diet low in bioavailable iron (27).

Requirements of absorbed iron are calculated by factorial modelling. The estimate is derived from the sum of basal iron losses, menstrual losses in women of fertile age, body iron accretion for growth and iron needed by foetus, placenta and expansion of the red cell mass in pregnancy, iron losses by milk in nursing women, and needs to maintain minimal iron stores to ensure normal function (14,15,19,28). Basal losses include obligatory losses of iron in the faeces, physiological blood loss and enterocyte desquamation, urine, sweat, and exfoliation of skin cells. Body iron stores, composition of the diet and rate of erythropoiesis influences the proportion of absorbed iron (22). The balance of dietary components that inhibit or enhance iron absorption have a crucial role in determining non-haeme iron absorption (22). However, because haeme-iron is absorbed intact into the enterocyte its absorption is practically not affected by the diet or diet related factors. The IOM calculated average dietary iron requirements assuming an average iron absorption that varies among the different age, gender and physiological groups (10% for infants 7 to 12 months, upper limit of 18% for children and adolescents, adults and lactating women, and an upper limit of 25% for pregnant women) (14). The FAO/WHO Expert Consultation estimated dietary iron requirements for subjects consuming diets of low (5%), intermediate (10%) and high iron bioavailability (15%) (28). The recent FAO/WHO expert committee on vitamin and minerals provided recommended intakes considering diets of 5, 10, 12 and 15% of iron bioavailability (19).

The Scientific Committee for Food of the European Commission utilised a value of 15% for iron bioavailability (15).

2. Zinc

Zinc is an essential trace element that is a catalytic component of over 300 enzymes, which also has a role in the structural integrity of proteins and membranes, in the union of hormones to its receptors, and in gene expression (29). Zinc is required for growth, normal development, DNA synthesis, immunity, and sensory functions. Manifestations of zinc deficiency include growth retardation, delayed sexual and skeletal maturation, alteration in cell-mediated immunity, impaired resistance to infections, anorexia, impaired taste, delayed wound healing, behavioural effects, skin lesions and alopecia (29-32). The true prevalence of zinc deficiency at a global level is not known because of the lack of sensitive indicators of zinc status (33). Ithas been estimated using information on the inadequacy of daily zinc intake in developing and industrialised countries. Recently, an UNICEF expert consultation group concluded that zinc deficiency is a prevalent problem in developing countries and that its magnitude should be very similar to that of iron deficiency (34).

Zinc requirements have been determined using factorial analysis. The value is based on the minimal amount of absorbed zinc necessary to replace daily excretion of endogenous zinc and tissue growth, zinc accretion during pregnancy and zinc losses by milk in the case of nursing women (12,14,15,19). Excretion of endogenous zinc by the intestine is the main component of zinc losses, while losses in urine, menses, semen and integument exfoliation contribute to a lesser extent (35). This serves to estimate the required amount of absorbed zinc to compensate for losses. Zinc absorption is inversely related to dietary intake and efficiency of absorption is influenced by the physical and chemical properties of zinc in foods and the interaction of zinc with absorption inhibitors and enhancers (36). Diets have been characterised as of low, intermediate and high zinc bioavailability, based on the composition of the diet (12). FAO/WHO/IAEA and FAO/WHO have provided recommendations for age and sex groups consuming diets with high, moderate and low availability (12,19), while IOM recommendations are based on studies in which zinc bioavailability was likely to be representative of typical diets in North America (14). For some life stage groupings requirements were corroborated by secondary indicators of zinc depletion and results of the effect of supplementation on biochemical and other laboratory parameters of zinc status, zinc intake and linear growth (12,14).

3. Copper

Copper is responsible for structural and catalytic properties of multiple enzymes necessary for normal body functions (37). This metal is required for infant growth, host defence mechanisms, bone strength, red and white cell maturation, iron transport and brain development (38). Anaemia, neutropenia, and bone abnormalities (osteoporosis, fractures, etc.) are the main manifestations of copper deficiency. Other effects described include hypopigmentation of the hair and skin, hypotonia, impaired growth, increased incidence of infections and altered immunity (37-39). In Menkes disease, a genetic form of copper deficiency, symptoms include abnormal spiral twisting of the hair, lax skin and articulations, tortuosity and dilatation of major arteries, varicosities of veins, retinal dystrophy, profound central nervous system damage, and death (38). Some epidemiological studies have shown an association between cardiovascular mortality with low copper intake and/or low serum copper levels (40-43). Acquired deficiency occurs mainly in young infants; however, it has also been diagnosed in children and in adults (38). Most cases have been described in malnourished children (37-40). The true global prevalence of copper deficiency is unknown, but it is associated with common conditions such as low birth weight and child malnutrition.

Copper requirements have been estimated from controlled studies in which the effects of copper intake on copper status were measured. Copper nutrition in infants and in adults has been evaluated using a combination of laboratory indicators (12,14,15). Requirements of children and adolescents were interpolated from the infant and adult data on requirements.

4. Iodine

Iodine is a critical component of thyroid hormones (44). Approximately 60% of the total body iodine is stored in the thyroid gland. Thyroid hormones are necessary for cell growth and differentiation, the maintenance of metabolic rate and overall cellular metabolism (45). Iodine deficiency is frequently observed in populations living in environments where the soil is devoid of iodine due to leaching by the action of glaciation, rain or floods. Twenty-nine percent of the world's population lives in areas at risk of iodine deficiency (46). Iodine deficiency induces enhanced iodine uptake by thyroid cells and an increase size of the thyroid gland (goitre). If these compensatory mechanisms are not enough to produce normal serum levels of thyroid hormones, symptoms and signs of hypothyroidism develop including impaired growth, mental retardation, and reproductive failure (47). Iodine deficiency is recognised as the most important preventable cause of mental retardation in the world today. The iodination of table salt has been introduced worldwide as a public health measure to eradicate iodine deficiency (47). The prevalence of this disorder has progressively declined in populations with access to this fortified product, however, there are large segments of the world's population that are not yet covered by these programs.

Requirements have been estimated from balance studies, thyroidal radiodine accumulation and turnover, and iodine intake necessary to maintain a normal thyroid size and to provide thyroid iodine stores sufficient for a normal thyroid hormone synthesis (14,15,19). Additional iodine needs during pregnancy were estimated based on the thyroid iodine content of new-born infants, iodine balance studies, and the effect of iodine supplementation on maternal thyroid volume and/or thyroid function (14,19).

5. Calcium

Calcium is the most abundant mineral in the body (1.5 – 2.0% of the total body weight). The total body content of an adult is approximately 1.2 Kg, 99% of which is stored in the skeleton and 1% in extra- and intracellular fluids and cellular membranes (13,15,48-50). In addition to its major function as a primary structural constituent of the skeleton, calcium is also important for the regulation of multiple enzymes and hormonal responses, blood clotting, nerve transmission, muscle contraction/relaxation (including normal heart rhythm), vascular contraction and vasodilation, and glandular secretion (13,48-51). Calcium deficiency leads to decrease in bone mineral content and mass that results in a weaker bone structure, leading to increased risk for bone fractures (13,48-51).

According to the IOM insufficient information is available to establish precise requirements, thus an AI is provided for each of the life stage groups. The AIs were derived from balance studies, factorial modelling using calcium accretion based on bone mineral accretion and clinical trials which evaluated the response/change in bone mineral content/density or fracture rate to varying calcium intakes (50). The Scientific Committee for Food of the European Commission utilised factorial analysis to estimate requirements for calcium (15). The recent FAO/WHO expert committee on vitamin and minerals provided recommended intakes considering the effect of protein and salt intake, thus calcium recommendations are substantially lower for populations in developing countries with lower salt and protein intakes (19). This is relevant since most populations in developing countries not consuming dairy products have difficulty meeting the traditional calcium recommendations based on data obtained in industrialised countries.

6. Phosphorus

Phosphorus as calcium phosphate (calcium hydroxyappatite) is a structural component of bones it is found in a 1:2 mass ratio relative to calcium (13,15, 48-50). Eighty-five percent of total body phosphorus is found in the skeleton. This element plays an important role as a structural component of cell membrane phospholipids; it is essential for energy production and storage, phosphorylation of numerous enzymes, hormones and cell signalling molecules, and to maintain a normal acid-base equilibrium (51,52). Phosphorus deficiency is rare at the population level, although it has been described in small premature infants exclusively receiving human milk, and in patients receiving aluminium hydroxide containing antacids over extended periods of time (13). Deficiency results in bone mass loss, muscle weakness, malaise, and pain (13).

Requirements of children and adolescents are calculated using a factorial approach based on body accretion in bone and soft tissues, efficiency of absorption and urinary excretion (50). Adult requirements are based on the relationship between serum inorganic phosphorus and dietary intake (50). The Scientific Committee for Food of the European Commission proposed the use of phosphorus intakes that correspond on a molar basis with that for calcium for estimating phosphorus requirements (15).

7. Magnesium

This element is the second most abundant intracellular cation. Adult body content is 20-28 g, 60-65% of which is found in the skeleton and 1% in extracellular fluid (15,53). Magnesium is a cofactor in over 300 enzymatic reactions (15,53). Magnesium is involved in the function of enzymes of carbohydrate, lipid, protein, and nucleic acid metabolisms (15,53). It is essential for the mineralisation and development of the skeleton, and also plays a role in cellular permeability and neuromuscular excitability (15,53).

Magnesium deficiency induces increased neuromuscular excitability, and it enhances potassium renal excretion (15,53). Deficiency of this element has been implicated in hypertension and type II diabetes (15,53). Low magnesium intake has been associated with an increased risk of cardiovascular disease (15,53).

Balance studies provided the basis for the estimation of magnesium requirement (50). Other criteria utilised to provide Mg recommendation are based on the relationship between magnesium intake and magnesium serum levels or magnesium and potassium content of the muscle, and on studies performed in young children recovering from malnutrition with diets containing different concentrations of this mineral (19). The Scientific Committee for Food of the European Commission provided a recommended intake based on observed acceptable range of intakes (15). In the FAO/WHO report 2002 (19) (Table 8), the upper limits of 65 mg for children ages 1-3 years, 110 mg for 4-10 years, and 350 mg for adolescents and adults are suggested as tolerable limits for the content of soluble magnesium in foods and drinking water based on the IOM report published in 1997 (50). However, according to IOM these upper limits are for non-food source, because magnesium has not been shown to produce any toxic effects when ingested as a naturally occurring substance in foods (50).

8. Fluoride

The essentiality of fluoride for humans has not been proven unequivocally (8,12,50). However, this element has beneficial effects on the prevention of dental caries due to the formation of crystalline hydroxyflurappatite leading to a more acid resistant enamel form (8,12,50). Because there is no sufficient available data to calculate requirements, an AI is provided based on the fluoride intake that reduce the occurrence of dental caries maximally, without causing untoward effects linked to excess exposure, such as fluorosis (stained enamel) (50).

9. Sodium, Potassium, and Chloride

Sodium is the principal cation in the extracellular fluid, while potassium is predominantly an intracellular cation, and chloride is the main extracellular anion (54,55). These electrolytes have important physiological roles in the maintenance of extracellular fluid volume, extra- and intracellular osmolarity, regulation of acid – base balance, generation of trans-membrane electrochemical gradients, transmission of nerve impulses, and muscle contractions (54,55). In addition to its functions as an electrolyte, chloride is indispensable for gastric hydrochloric acid production (54,55).

Hyponatremia is the most common electrolyte disorder (55). This deficiency usually is the consequence of excessive losses from the body, commonly occurring during prolonged and/or severe diarrhoea or vomiting, or in hot, humid conditions in which a large amount of sodium is lost in sweat (55). Manifestations of hyponatremia, cerebral oedema and neuromuscular hyperexcitability, are the consequences of changes in extracellular fluid volume (55). Symptoms of CNS dysfunction are the most common. Dehydration or metabolic acidosis usually accompanies sodium deficit and these are commonly responsible in part for the clinical findings (55). Signs of sodium deficiency include cramps, weakness, fatigue, nausea, mental apathy, low blood pressure, confusion and seizures (55).

Hypokalemia, low serum potassium, usually occurs as a consequence of increased gastrointestinal losses due to diarrhoea or vomiting (55). Muscle weakness, muscle cramping, paralytic ileus, and cardiac arrhythmia characterise this condition (55).

Deficiency of chloride is rare and results from excessive gastrointestinal loss of chloride-rich fluids (e.g. prolonged episodes of vomiting, diarrhoea) and is associated with a metabolic alkalosis (55).

Balance studies, factorial analysis, daily intakes and biochemical indicators provided the basis for the estimation of sodium and potassium minimum requirements of healthy subjects proposed by the US National Research Council (13) as well as for the acceptable range of intakes for sodium and chloride or population reference intakes for potassium proposed by the Scientific Committee for Food of the European Commission (15). Because both the intakes and losses of chloride normally matched those of sodium, the minimum requirements and acceptable range of intakes of chloride should match those for sodium.

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Table 1. Recommended daily intakes (iron, zinc and copper) for infants and children.

Group	Years	Fe (mg)			Zn (mg)			Cu (mg)		
		I[a,c]	II[d]	III[e]	I[b,c]	II[d]	III[e]	IV[f]	II[d]	III[e]
Infants	0-0.25		0.27[g]		1.1 2.8 6.6	2		0.33-0.55	0.2[g]	
	0.25-0.5		0.27[g]		1.1 2.8 6.6	2[g]		0.37-0.62	0.2[g]	
	0.5-1	6.2 7.7 9.3 18.6	11	6	2.5 4.1 8.4	3[g]	4	0.6	0.22[g]	0.3
Children	1-2	3.9 4.8 5.8 11.6	7	4	2.4 4.1 8.3	3	4	0.56	0.34	0.4
	3	3.9 4.8 5.8 11.6	7	4	2.4 4.1 8.3	3	4	0.56	0.34	0.4
	4-5	4.2 5.3 6.3 12.6	10	4	2.9 4.8 9.6	5	6	0.57	0.44	0.6
	6	4.2 5.3 6.3 12.6	10	4	2.9 4.8 9.6	5	6	0.57	0.44	0.6
	7-8	5.9 7.4 8.9 17.8	10	6	3.3 5.6 11.2	5	7	0.75	0.44	0.7
	9-10	5.9 7.4 8.9 17.8	8	6	3.3 5.6 11.2	8	7	0.75	0.70	0.7

I (19), II (14), III (15), IV (12)

[a] Diet of 5%, 10%, 12% and 15% bioavailability.

[b] Diet of high, moderate and- low bioavailability.

[c] Recommended nutrient intake.

[d] Recommended dietary allowances.

[e] Population reference intakes.

[f] Lowest limit of the population mean intake to meet normative needs.

[g] Adequate intake.

Table 2. Recommended daily intakes (iodine, calcium, phosphorus, magnesium and fluoride) for infants and children.

Group	Years	I (ug)			Ca (mg)		P (mg)		Mg (mg)	F (mg)
		I[a]	II[b]	III[c]	V	III[c]	V[b]	III[c]	V[b]	V
Infants	0-0.5	90	110[d]		210[d]		100[d]		30[d]	0.01[d]
	0.5-1	90	130[d]	50	270[d]	400	275[d]	300	75[d]	0.5[d]
Children	1-3	90	90	70	500d	400	460	300	80	0.7[d]
	4-6	90	90	90	800d	450	500	350	130	1.0[d]
	7-8	120	90	100	800d	550	500	450	130	1.0[d]
	9-10	120	120	100	1300[d]	550	1250	450	240	2.0[d]

I (19), II (14), III (15), V (50)

[a] Recommended nutrient intake.

[b] Recommended dietary allowances.

[c] Population reference intakes.

[d] Adequate intake.

Table 3. Recommended daily dietary intakes (sodium, potassium and chloride) for the different life stage groups.

Group (years)	Na (mg)		K (mg)		Cl (mg)
	VI[b]	III[c]	VI[b]	III[d]	VI[b]
0-0.5 [a]	120		500		180
0.5-1 [a]	200		700	800	300
1 [a]	225		1000	800	350
2-3 [a]	300		1400	800	500
4-5 [a]	300		1400	1100	500
6 [a]	400		1600	1100	600
7-9 [a]	400		1600	2000	600
10 *	500		2000	2000	750
11-17 [a]	500		2000	3100	750
$\geq$18 [a]	500	575-3500	2000	3100	750
Pregnancy	500			3100	
Lactation	500			3100	

III (15), VI (13)

[a] Males and females.

[b] Minimum requirements.

[c] Acceptable range of intakes.

[d] Population reference intakes.

Table 4. Recommended daily intakes (iron, zinc and copper) for males.

Group (years)	Fe (mg)						Zn (mg)					Cu (mg)		
	I[a,c]				II[d]	III[e]	I[b,c]			II[d]	III[e]	IV[f]	II[d]	III[e]
11-12	9.7	12.2	14.6	29.2	8	10	5.1	8.6	17.1	8	9.0	0.73	0.70	0.8
13	9.7	12.2	14.6	29.2	8	10	5.1	8.6	17.1	8	9.0	1.00	0.70	0.8
14	9.7	12.2	14.6	29.2	11	10	5.1	8.6	17.1	11	9.0	1.00	0.89	0.8
15	12.5	15.7	18.8	37.6	11	13	5.1	8.6	17.1	11	9.0	1.00	0.89	1.0
16	12.5	15.7	18.8	37.6	11	13	5.1	8.6	17.1	11	9.0	1.33	0.89	1.0
17	12.5	15.7	18.8	37.6	11	13	5.1	8.6	17.1	11	9.0	1.33	0.89	1.0
18	9.1	11.4	13.7	27.4	11	9	5.1	8.6	17.1	11	9.0	1.33	0.89	1.1
$\geq$19	9.1	11.4	13.7	27.4	8	9	4.2	7.0	14.0	11	9.5	1.35	0.90	1.1

I (19), II (14), III (15), IV (12)
[a] Diet of 5%, 10%, 12% and 15% bioavailability.
[b] Diet of high, moderate and- low bioavailability.
[c] Recommended nutrient intake.
[d] Recommended dietary allowances.
[e] Population reference intakes.
[f] Lowest limit of the population mean intake to meet normative needs.

Table 5. Recommended daily intakes (iron, zinc and copper) for females.

Group (years)	Fe (mg)						Zn (mg)				
	I[a,c]				II[d]	III[e]	I[b,c]			II[d]	III[e]
11-12	9.3	11.7	14.0	28.0	8	22	4.3	7.2	14.4	8	9
13	9.3	11.7	14.0	28.0	8	22	4.3	7.2	14.4	8	9
14	9.3	11.7	14.0	28.0	15	22	4.3	7.2	14.4	9	9
15	20.7	25.8	31.0	62.0	15	21	4.3	7.2	14.4	9	7
16-17	20.7	25.8	31.0	62.0	15	21	4.3	7.2	14.4	9	7
18	19.6	24.5	29.4	58.8	15	20	4.3	7.2	14.4	9	7
≥19	19.6	24.5	29.4	58.8	18	20	3.0	4.9	9.8	8	7
Post-menopausal	7.5	9.4	11.3	22.6	8	8	3.0	4.9	9.8		
Pregnancy											
1st trimester					27		3.4	5.5	11.0	11 (13)[g]	7
2nd trimester					27		4.2	7.0	14.0	11 (13)[g]	7
3rd trimester					27		6.0	10.0	20.0	11 (13)[g]	7
Lactation											
0-3 mo	10.0	12.5	15.0	30.0						12 (14)[g]	12
3-6 mo	10.0	12.5	15.0	30.0						12 (14)[g]	12
6-12 mo	10.0	12.5	15.0	30.0						12 (14)[g]	12

Group (years)	Cu (mg)		
	IV[f]	II[d]	III[e]
11-12	0.77	0.70	0.8
13	1.00	0.70	0.8
14	1.00	0.89	0.8
15	1.00	0.89	1.0
16-17	1.15	0.89	1.0
18	1.15	0.89	1.1
≥19	1.15	0.90	1.1
Pregnancy	1.15	1.00	1.1
Lactation	1.25	1.30	1.4

I (19), II (14), III (15), IV (12)
[a] Diet of 5%, 10%, 12% and 15% bioavailability.
[b] Diet of high - moderate - low bioavailability.
[c] Recommended nutrient intake.
[d] Recommended dietary allowances.
[e] Population reference intakes.
[f] Lowest limit of the population mean intake to meet normative needs.
[g] in parenthesis are values for pregnant women ≤18 years old.

Table 6. Recommended daily intakes (iodine, calcium, phosphorus, magnesium and fluoride) for males.

Group (years)	I (ug)			Ca (mg)		P (mg)		Mg (mg)	F (mg)
	I[a]	II[b]	III[c]	V	III[c]	V[b]	III[c]	V[b]	V
11-12	120	120	120	1300[d]	1000	1250	775	240	2.0[d]
13	150	120	120	1300[d]	1000	1250	775	240	2.0[d]
14	150	150	120	1300[d]	1000	1250	775	410	3.0[d]
15-17	150	150	130	1300[d]	1000	1250	775	410	3.0[d]
18	150	150	130	1300[d]	700	1250	550	410	3.0[d]
$\geq$19	150	150	130	1300[d]	700	700	550	400	4.0[d]
$\geq$31								420	
$\geq$51				1200[d]					

I (19), II (14), III (15), V IOM (50)

[a] Recommended nutrient intake.

[b] Recommended dietary allowances.

[c] Population reference intakes.

[d] Adequate intake.

Table 7. Recommended daily intakes (iodine, calcium, phosphorus, magnesium and fluoride) for females.

Group (years)	I (ug)			Ca (mg)		P (mg)		Mg (mg)	F (mg)
	I[a]	II[b]	III[c]	V	III[c]	V[b]	III[c]	V[b]	V
11-12	120	120	120	1300[d]	800	1250	625	240	2.0[d]
13	150	120	120	1300[d]	800	1250	625	240	2.0[d]
14	150	150	120	1300[d]	800	1250	625	360	3.0[d]
15-17	150	150	130	1300[d]	800	1250	625	360	3.0[d]
18	150	150	130	1300[d]	800	1250	550	360	3.0[d]
≥19	150	150	130	1000[d]	700	700	550	310	
≥31									
≥51				1200[d]				320	
Pregnancy									
≤18	200	220	130	1300[d]	700	1250	550	400	3.0[d]
19-30	200	220	130	1000[d]	700	700	550	350	3.0[d]
31-50	200	220	130	1000[d]	700	700	550	360	3.0[d]
Lactation									
≤18	200	290	160	1300[d]	1200	700	950	360	3.0[d]
19-30	200	290	160	1000[d]	1200	700	950	310	3.0[d]
31-50	200	290	160	1000[d]	1200	700	950	320	3.0[d]

I (19), II (14), III (15), V IOM (50).

[a] Recommended nutrient intake.

[b] Recommended dietary allowances.

[c] Population reference intakes.

[d] Adequate intake

Table 8. Upper limit of daily dietary intakes (iron, zinc, copper, iodine, calcium, phosphorus, magnesium and fluoride) for the different life stage groups.

Group (years)	Fe (mg)		Zn (mg)			Cu (mg)			I(ug)		Ca(g)	P(g)	Mg(mg)		F(mg)
	II[c]	II[c]	III[e]	IV[d]	IV[f]	II[c]	III[e]	I[d]	II[c]	III[e]	V[c]	V[c]	I[d]	III[e]	V[c]
0–0.5	40	4	7		150[b]			150[b]							0.7
0.6–12	40	5	7	13	150[b]			140[b]							0.9
1-2	40	7	10	23	1.5	1	1	50[b]	200	200	2.5	3	65		1.3
3	40	7	10	23	1.5	1	1	50[b]	200	200	2.5	3	65		1.3
4-6	40	12	10	23	1.5	3	2	50[b]	300	250	2.5	3	110	250	2.2
7-8	40	12	13	28	3	3	4	50[b]	300	300	2.5	3	110	250	2.2
9-10	40	23	13	28	3	5	4	50[b]	600	300	2.5	4	350	250	10.0
11-12	40	23	18	32 36[a]	6	5	4	50[b]	600	450	2.5	4	350	250	10.0
13	40	23	18	36 40[a]	8	5	4	30[b]	600	450	2.5	4	350	250	10.0
14	45	34	18	36 40[a]	8	8	4	30[b]	900	450	2.5	4	350	250	10.0
15	45	34	22	36 40[a]	8	8	4	30[b]	900	500	2.5	4	350	250	10.0
16-17	45	34	22	38 48[a]	10	8	4	30[b]	900	500	2.5	4	350	250	10.0
18	45	34	25	38 48[a]	10	8	5	30[b]	900	600	2.5	4	350	250	10.0
≥ 19	45	40	25	35 45[a]	10	10	5	30[b]	1100	600	2.5	4	350	250	10.0

I (19), II (14), III (15), IV (12), V (50).

[a] females & males, respectively.
[b] ug/kg/d.
[c] Tolerable upper intake level.
[d] Upper tolerable nutrient intake level.
[e] Tolerable upper intake levels.
[f] Upper limit of the safe range of population mean intakes.

Table 9. WHO Guidelines for drinking water (2-4,56).

	WHO Guideline (mg/L)
Iron	0.3[a]
Zinc	3.0[a]
Copper	2.0[b]
Iodine	N/A
Calcium	N/A
Phosphorus	N/A
Magnesium	N/A
Fluoride	1.5[b]
Sodium	200[a]
Potassium	N/A
Chloride	250[a]

[a] Levels likely to give rise to consumer complaints.
[b] Guideline Value.
N/A = non available.