IAEA
International Atomic Energy Agency

Improving Nutrition Through Nuclear Science

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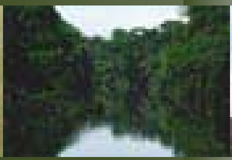




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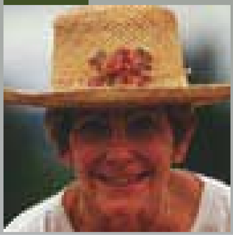

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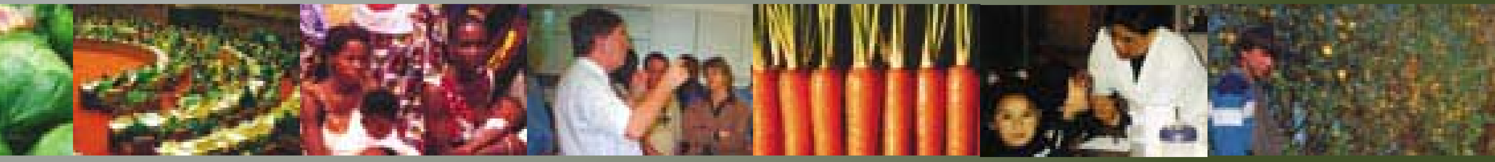
Good nutrition is essential to health and quality of life. As a United Nations agency dedicated to helping Member States achieve their social and economic goals, the International Atomic Energy Agency (IAEA) recognizes the importance of good nutrition and is working to address the problems underlying poor nutrition. In fact, many Agency activities serve basic human needs, by applying nuclear science to increase food production, improve health care, improve management of water resources, and assess sources of environmental pollution.

Global progress in reducing malnutrition throughout the human life cycle has been slow and patchy. In its 2000 Report on the World Nutrition Situation, the United Nations Sub Committee on Nutrition estimated that in developing countries 182 million children under five years of age are chronically undernourished and 150 million are underweight. An estimated 30 million infants are born each year with impaired growth due to poor nutrition during pregnancy.

Worldwide, renewed international commitments have been made to address this situation, and the IAEA is a vital partner in these efforts. Nuclear science provides valuable tools for monitoring factors that influence nutrition, such as micronutrients, body composition, and breast milk uptake. Through its sub-programme on nutrition, the Agency is helping countries apply these tools to their nutritional problems and is supporting leading-edge research on the interaction between nutrition and environmental pollution and infection with the ultimate goal of improving human nutrition.



Improving Nutrition Through Nuclear Science

IAEA Programmes

The economic and social costs of malnutrition are enormous and major international efforts are underway to address the underlying problems.

Nuclear science — most often associated with things like X rays, radiation therapy, or nuclear power plants — is today being used by countries around the world to identify nutritional problems and to evaluate the effectiveness of the interventions. The International Atomic Energy Agency (IAEA) is leading the way, providing assistance and support to developing countries to:

— verify the nature of the nutritional problem;

— monitor the effectiveness and reduce costs of nutrition programmes;

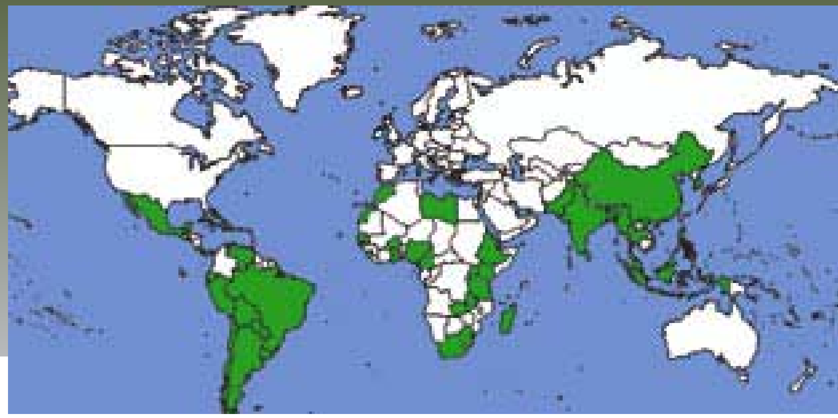
— serve as early indicators of important long term health improvements; and

— determine environmental conditions and assess the consequences on human health and nutritional status.

The goal of these programmes is to build the capacity needed in developing countries to use nuclear techniques to address nutritional problems. The IAEA builds this capacity by training scientists through fellowships and workshops, supports expert missions, and provides needed equipment through Co-ordinated Research Projects (CRPs) and Technical Co-operation (TC). The Agency also promotes post-graduate (PhD) level research and training in nutrition.

The IAEA provides assistance through Co-ordinated Research Projects (CRPs) that encourage institutes to collaborate on well-defined research projects. Designed to help developing countries adapt state-of-the art techniques to their particular situation, CRPs are promoting high quality research on nutrition in countries around the world (shown in red).

Participants at an IAEA Workshop on Nutrition in Ghana. N. Mokhtar/IAEA



Technical Co-operation Projects (TC) work to build scientific and technical capacity and supporting infrastructure in developing countries. Nuclear techniques have been transferred to developing countries around the world (shown in green) to help them identify their nutritional problems and evaluate the effectiveness of their intervention programmes. The results are being used to improve national policies and strategies on human nutrition.

IAEA-assisted laboratory in the Philippines.
IAEA Project: RAS/7/010

Micronutrients play an essential role in the metabolic processes of the human body, but are only required in small quantities.

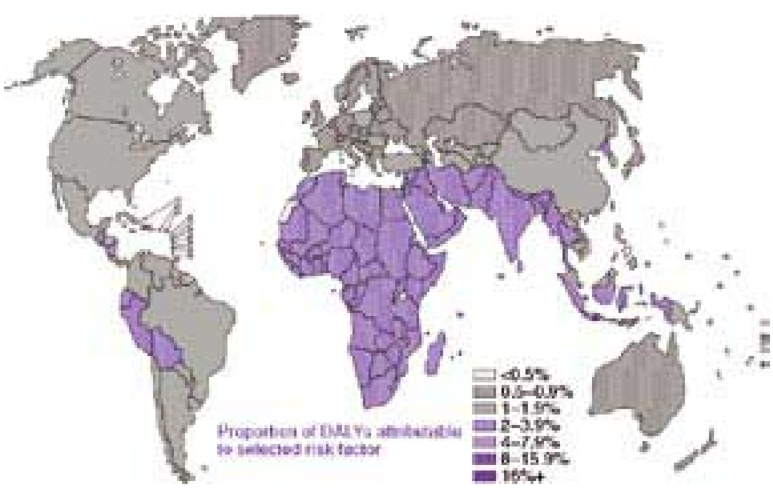
Because of their essential role, when micro–nutrients are not sufficient from food in the diet, significant health problems can result.

Micronutrient Deficiency: A Global Challenge to Health

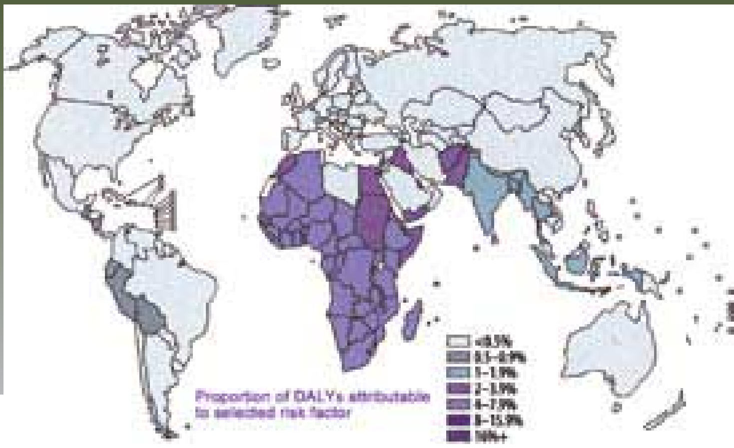
In its 2002 report, the World Health Organization (WHO) estimates that approximately 168 million children under five years of age are underweight, meaning they do not get enough nutrients to meet their bodys' needs. Multiple micronutrient deficiencies, such as from iron, zinc, and vitamin A, are affecting the lives and health of billions of people in the developing world.

Iron Deficiency

Iron deficiency is the most prevalent nutritional deficiency worldwide. It is a major public health problem with adverse consequences particularly for women of reproductive age and for young children.



Global Distribution of Iron Deficiency. *One DALY (disability-adjusted life year) equals the loss of one healthy life year. Source: World Health Organization*



Global Distribution of Vitamin A Deficiency.
Source: World Health Organization

Child in Brazil.
IAEA Project:
RLA/7/008

When there is not enough iron in the body, fewer red blood cells are produced. This reduces the capacity of the blood to transport oxygen. As a result, symptoms, ranging from fatigue and inability to concentrate, to impaired physical and cognitive development of children, can occur. Iron deficiency anaemia may also cause problems during pregnancy particularly in developing countries, where it can increase the risk of premature delivery, as well as the risk of maternal and foetal complications and death.

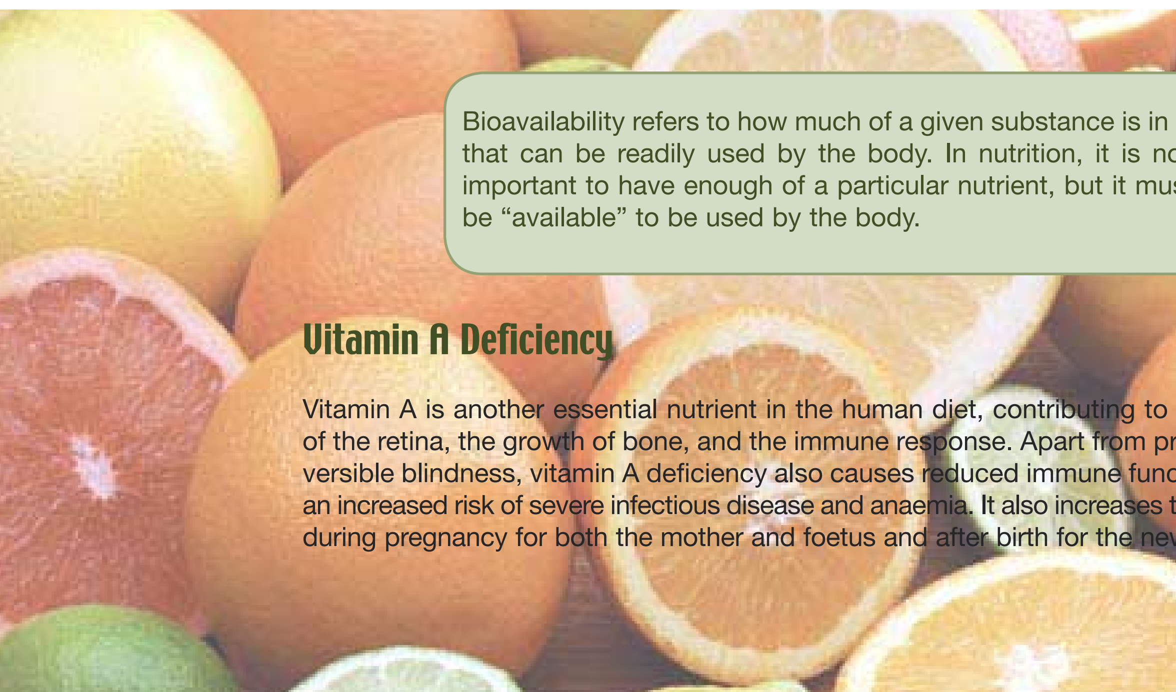
The most common reason for iron deficiency anaemia, especially among infants and children, is due to inadequate iron from food. Parasites, infections, stomach and digestive diseases, and blood loss during menstruation may also worsen anaemia.

Zinc Deficiency

Zinc is an important nutrient. It is an essential part of many enzymes (a protein molecule that catalyzes chemical reactions in the body) and plays an important role in protein synthesis and cell division. The health consequences of zinc deficiency include: poor immune system function, growth retardation, and delayed sexual maturity in children. Zinc deficiency is caused by low intake and/or low absorption of bioavailable zinc. Diets low in meat and fish increase the risk of zinc deficiency, because zinc is poorly bioavailable in cereals.

Fish are a good source of zinc.
J. Ford/IAEA

PhotoDisc



Bioavailability refers to how much of a given substance is in a form that can be readily used by the body. In nutrition, it is not only important to have enough of a particular nutrient, but it must also be “available” to be used by the body.

Vitamin A Deficiency

Vitamin A is another essential nutrient in the human diet, contributing to the functioning of the retina, the growth of bone, and the immune response. Apart from preventable, irreversible blindness, vitamin A deficiency also causes reduced immune function, leading to an increased risk of severe infectious disease and anaemia. It also increases the risk of death during pregnancy for both the mother and foetus and after birth for the newborn.

Stable isotope techniques and radioisotopic methods are the only reliable tools available to determine the absorption, retention or utilization of a nutrient by human body. Stable isotopes are being used in bioavailability studies in the Philippines. IAEA Project: RAS/7/010

Vitamin A deficiency occurs when too little vitamin A is taken in and absorbed from food. Vitamin A also comes from beta-carotene, a precursor found in fruits and vegetables, however, investigations have shown that beta-carotene is not as bioavailable as once thought, meaning that more must be eaten to get an adequate amount of vitamin A. An estimated 250 million pre-school children in developing countries are affected by Vitamin A deficiency, although severe deficiency that causes blindness is declining.

Alleviating Micronutrient Deficiency: Isotopes in Action

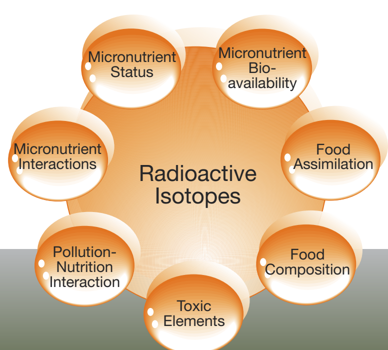
Around the world, approaches to improve the intake of micronutrients include nutritional supplementation programmes, fortification of staple foods, modification of traditional diets, and control of parasites and infections.

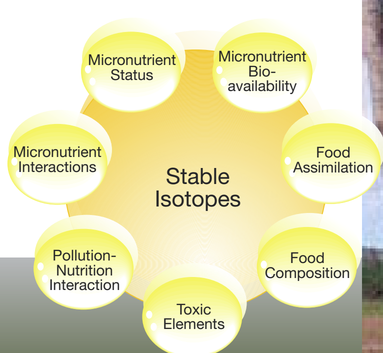
In supplementation programmes, those at risk of deficiency are given the nutrients in capsule or syrup forms. Fortification programmes add micronutrients to staple foods, such as flour or oil, as a means of providing them to people on a large scale. Promoting the diversification of foods in the diet may also improve the absorption of essential micronutrients. Controlling parasites, particularly worms, can also help prevent deficiencies.

Information about the nutritional status of individuals and populations is essential in order to initiate any intervention. This information comes from evaluating measurements of nutrient requirements and studies of the uptake and bioavailability of vitamins and minerals. Over the last 20 years, developments in nuclear science have provided new techniques and methods that are today being used to gather such information.

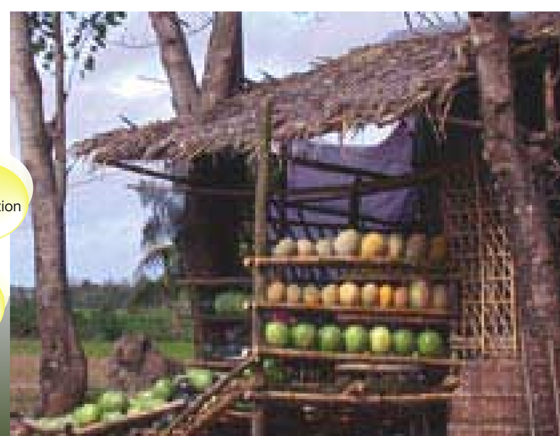
There are two forms of isotopic tracers: stable and radioactive. Radioactive isotopic tracers can be measured by the radiation they emit. While these types of tracers are often used in environmental studies or medical diagnosis, stable isotopes are usually used in nutritional studies, especially those involving infants and young children.

Both stable and radioactive isotopes are used in nutritional and environmental studies.





Selling fruit in the Philippines. R. Quevenco/IAEA



Saliva samples in Senegal are used to study how much breast milk a nursing baby receives. IAEA Project: Senegal/7/003

Stable isotopes do not emit radiation. In nature, most elements occur as a mixture of two or more stable isotopes, which differ only in the number of neutrons present in their nuclei.

Stable isotopes can be given orally in water, food, or a capsule. Depending on the rate of absorption, these stable isotopes will be incorporated into metabolic products, such as body water, urea, or carbon dioxide that the body produces. By measuring these metabolic products in saliva, breast milk, urine, breath, or stool, the ratio of minor to major isotopes can be determined.

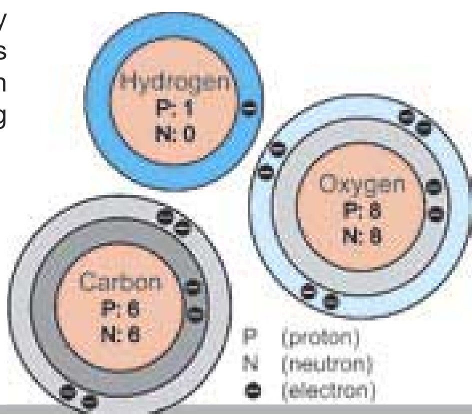
Specialized equipment is used to measure stable isotopes in samples

Mass spectrometers are used to quantify the number of atoms or molecules present in a sample, by "weighing" the atoms present using their mass-to-charge ratio.

Infrared absorption spectroscopy is used to identify and measure organic and organometallic molecules in samples by detecting how they react with specific wavelengths of infrared light.

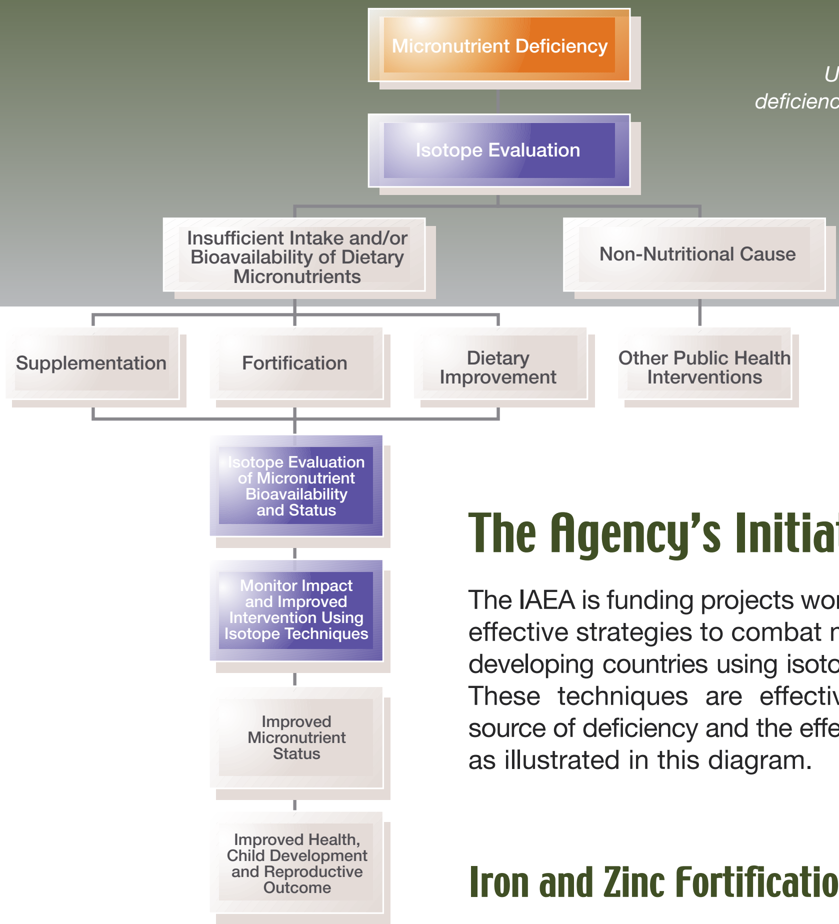
Atomic emission spectroscopy is used to determine the concentration of compounds in a sample by measuring how the atoms present in the sample react when energy is applied.

The uptake and metabolism of micronutrients labelled with stable isotopes can be traced *in vivo* (a Latin term meaning "in life" and is used to describe a test in a living being rather than a test tube). Because stable isotopes have virtually no health risk in their use, they can be used in measured amounts to trace how the micronutrients are metabolized by the body. This technique is considered the "gold standard" for iron and other nutrient bioavailability studies in humans. It is being widely used to measure the effectiveness of fortification and supplementation programmes in several developing countries.



Light elements like oxygen, hydrogen, and carbon are used as stable isotopes in nutritional studies.

Middle: Infrared spectroscopy/IAEA. IAEA Project: Senegal/7/003
Bottom: Saliva samples in Mexico, as part of study on the effectiveness of nutritional programmes. IAEA Project: RLA/7/008



Using isotopes to assess nutritional deficiencies and evaluate the effectiveness of interventions.

The Agency's Initiative

The IAEA is funding projects worldwide aimed at developing effective strategies to combat micronutrient malnutrition in developing countries using isotopic and nuclear techniques. These techniques are effective in both evaluating the source of deficiency and the effectiveness of the intervention as illustrated in this diagram.

Iron and Zinc Fortification of Foods

An estimated 50 per cent of preschool children in Indonesia are deficient in iron and zinc. In response, the government has decided to fortify wheat flour with iron and zinc. Through a TC regional project isotopic techniques are being used to study the bioavailability of iron and to assess the interaction between zinc and iron added to the flour. The results: iron sulfate from fortified flour is well absorbed (15 per cent), but when zinc sulfate is also added to the flour, the interaction reduces the bioavailability of iron sulfate. In contrast, zinc oxide does not affect the bioavailability of iron.

Anaemia is prevalent among women and children in China. Through the TC regional Asia project, the iron status of school children consuming iron-fortified sauce was evaluated over a three-month period. The results: fortification was successful in restoring the iron level of the anaemic children to normal levels.

Despite considerable progress to address malnutrition in Thailand in recent years, pockets of malnutrition and micronutrient deficiencies still persist. As part of the regional project, the Institute of Nutrition in Mahidol University, Bangkok has been investigating the fortification of fish sauce. The next phase will use isotopic techniques to study the bioavailability of iron in women of childbearing age who are given the different formulations of the fortified sauce.

Fish sauce — a staple of the Thai diet — is being used in iron fortification studies.
J. Ford/IAEA

Saliva sampling in Chile.
IAEA Project: RLA/7/008

Healthier Lives in Latin America

"About 80 million rural and urban people in Latin America are covered to some degree by national nutrition programmes, costing billions of dollars," noted Dr. R. Uauy, former Director of the Institute of Nutrition and Food Technology in Chile. "Without careful measurements of the body's intake and use of vitamins and minerals, the programmes cannot be as effective".

The IAEA project is providing such measurements in Brazil, Chile, Cuba, and Mexico using stable isotopes. The data being acquired through the use of these techniques are — for the first time — being used to set nutrition guidelines tailored to local conditions and needs. In Chile, for example, the data resulted in the government's decision to modify its pre-school nutrition intervention programme. The result: within one year, anaemia prevalence was reduced by 20 per cent.

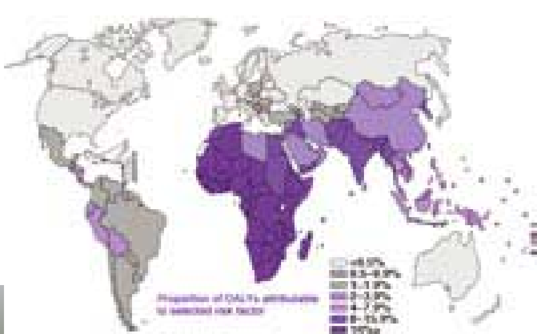
Vitamin A Assessment

To address the problem of adequate vitamin A in children and pregnant or nursing women, the IAEA has provided support to use isotopic techniques to measure the whole body vitamin A of those participating in: supplementation programmes in Ghana and Peru; diet improvement programmes in China, India, the Philippines, and Thailand; and food fortification programmes in Israel and the Philippines.

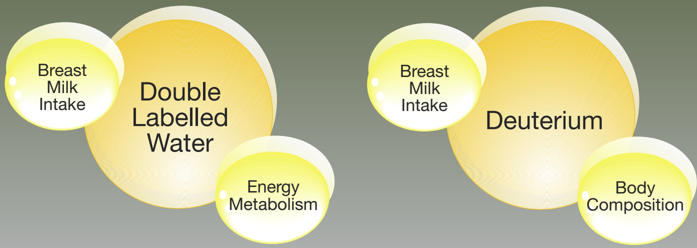
In Peru, evaluation of the plasma vitamin A levels using isotopic techniques has shown the positive effect of the supplementation programme. In the Philippines, isotope measurement of vitamin A found that there is an improvement in the amount of vitamin A stored in the liver of those participating in the fortification programme.

Energy Intake: Maintaining the Nutritional Balance

Our bodies use food energy (calories) to fuel muscle movements and metabolic processes. Too few calories sap the body of needed strength for day-to-day activities and, over time, can be a serious threat to health. Too many calories can cause weight gain and related health complications, such as diabetes and heart disease. Rates of overweight and obesity have been rising steadily over the past century. According to the WHO, more than 1 billion adults worldwide are overweight and at least 30 million are clinically obese.



Global Distribution of Underweight. *Source: World Health Organization*

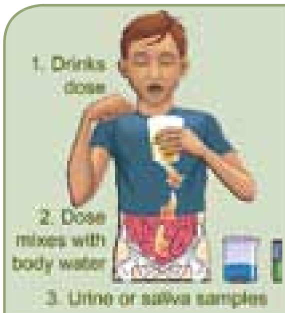


Stable isotope techniques used in nutritional studies

Nuclear and isotopic techniques can be used to study important parameters of human nutritional status, such as total energy expenditure, lean body mass, and breast milk intake. The results from these studies can help guide nutritionists in customizing nutrition programmes to provide calories and nutrients in a healthy balance to meet specific needs.

Total Energy Expenditure and Body Composition

Doubly labelled water ($^2H_2{}^{18}O$) — so-called because both the hydrogen and oxygen components of water are labelled with stable isotopes — is the only technique available to accurately measure how much food energy people use. This technique has gained wide acceptance. It is accurate and can be used under field conditions.



The ($^2H_2{}^{18}O$) doubly-labelled-water method for measuring total body water, body composition and energy expenditure

Total Body Water

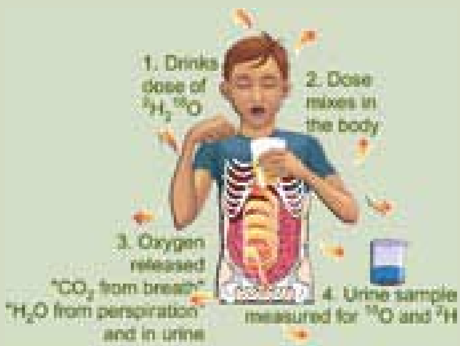
— Person drinks a dose of water containing stable isotopes of both hydrogen and oxygen ($^2H_2{}^{18}O$)

— Isotopes of both H and O mix with normal H and O in the body water within a few hours

— The ratio of ^2H:^1H is measured in urine or saliva to calculate the body water volume

Body Composition

— Total body weight is used to quantify fat-free mass. Fat mass is calculated as the arithmetic difference between body weight and fat-free mass.



Total Energy Expenditure

— The body produces carbon dioxide (CO_2) and water (H_2O). CO_2 is lost from the body via the breath and H_2O is lost through breath, skin, and urine

— ^{18}O is contained in both CO_2 and H_2O and will be lost from the body faster than ^2H. The rate of loss is measured by changes in urine over the next 7–12 days

— The difference between the rate of loss of ^{18}O and ^2H is used to calculate CO_2 production, which in turn is used to calculate energy expenditure

The results of investigations on energy expenditure of young children in Cuba are being used by the FAO/WHO/UNU to establish new energy recommendations. Prior to this project, no data existed for developing countries that could provide a scientific basis for food programmes suited to the local needs and conditions. The data indicate that the existing values actually overestimate the energy needs in children below 7 years old and may be contributing to growing pattern of obesity being observed in children in the region.

Energy expenditure study in children in Cuba.
IAEA Project: RLA/7/008

An IAEA-supported project in Chile used measurements of lean body mass to determine energy requirements in preschool children. As a result, the energy intake of the food supplements supplied to these children was reduced in order to prevent obesity.
Childhood obesity assessment in Chile.
IAEA Project: RLA/7/008

Lean Body Mass

Determining lean body mass and fat mass can help identify risks for over-nutrition. While it is a well recognized problem in developed countries, obesity is an increasing problem in countries considered to be in “nutrition transition”.

A dose of labelled water (^{2}H or ^{18}O) is given and allowed to equilibrate for a few hours. The extent of dilution of the tracer in body water is measured by sampling saliva, urine or plasma. Total body water (TBW) is then calculated using a specific equation. TBW is used to quantify lean body mass. Fat mass is the difference between body weight and free fat mass.

Breastfeeding is the simplest, healthiest, and least expensive way to feed infants. But a nursing infant’s nutrition depends both on the quantity and quality of the mother’s milk.

Breast Milk Intake

Senegal and Ghana are studying how supplementation programmes for nursing mothers are affecting their breast milk. The IAEA is providing technical support to use stable isotopes as part of this research, also supported by the World Bank, World Food Programme, and the German *Kreditanstalt für Wiederaufbau.* The results showed that breast milk output was not influenced by supplementation 60 days before delivery, however the quality of the milk, particularly the lactose, total protein, and zinc contents, increased significantly in supplemented mothers.

Ghana breast milk intake assessment.
IAEA Project: GHA/6/011

Using Stable Isotopes to Measure Breast Milk Intake

Stable isotopes are used to measure how much breast milk a baby receives when nursing.

— $^{2}H_2O$ is given by mouth to the mother

— ^{2}H enters the baby via breast milk and mixes with all the water in the baby’s body

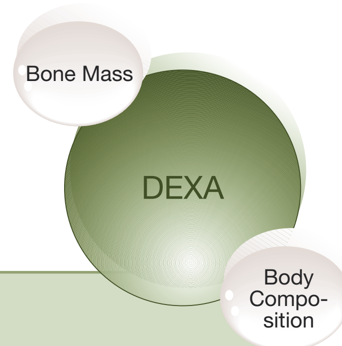
— ^{2}H is measured in the baby’s urine or saliva

— The rate of ^{2}H appearance in the baby, measured in spot urine or saliva collections, is proportional to breast milk intake

PhotoDisc

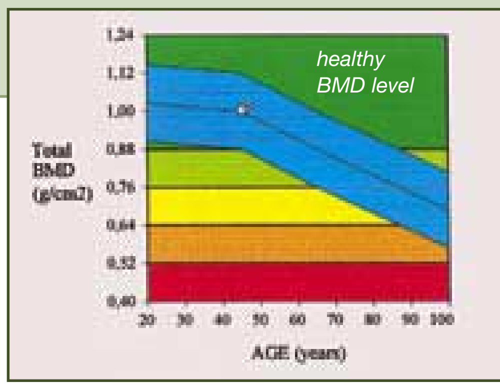
Osteoporosis: A Challenge to Healthy Ageing

Roughly 200 million men and women are affected by osteoporosis — the gradual decline in the amount and strength of bone tissue that occurs with age. Osteoporosis increases the fragility of bone and the likelihood of fractures and is one of the common problems of old age. Fractures can be a serious health concern, not only affecting mobility, but also quality of life of the elderly. While bone mineral mass is dependent of several factors, inadequate nutrition plays a key role in the development of osteoporosis. Calcium, vitamins D and C, and other minerals (phosphorus, magnesium, copper, manganese, fluoride, and zinc) are essential to healthy bone growth throughout life and can help prevent osteoporosis. While promoting healthy nutrition and active lifestyles will reduce the risk of osteoporosis, information is also needed to help diagnose this condition and identify those at risk of fractures.



Dual Energy X Ray Absorptiometry (DEXA)

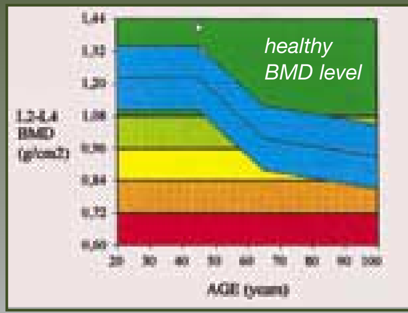
DEXA uses low energy X rays to measure body composition, especially bone mineral density. By determining how much of the X rays are absorbed by the bone, DEXA can precisely determine the bone mineral content. Data can be standardized for age, weight, height, and ethnicity, making it the technique of choice for assessing bone mineral density.



Bone scan of the hip joint shows loss of mass over time due to ageing (in blue). Healthy bone mineral density (BMD) level is shown in green on the graph.

The Agency's Initiative

Although a number of non-invasive techniques are capable of determining bone mass, harmonization of these measurements remains difficult because of the diversity of the techniques used. The IAEA has initiated studies to improve the comparability of data derived from different countries and allow researchers to draw multi-country conclusions from these data sets.



Bone scan of the spine. Graph shows changes in bone mineral density (BMD) over time (in blue). Healthy BMD level is shown in green.

A Co-ordinated Research Project (CRP) studied the differences in bone mineral density of young adults in 10 countries: Brazil, India, Chile, China, Croatia, Hungary, the Philippines, Russia, South Africa, and Singapore. Approximately 12 to 20 per cent of the global variation in bone mineral density was found to be due to differences between the actual measurement techniques, while 4 to 10 per cent were accounted for by the country of origin. In this study, significant differences were found in young adult bone mass, which, if persisting into old age, may contribute to a 2–3-fold increase in the risk of bone fracture.

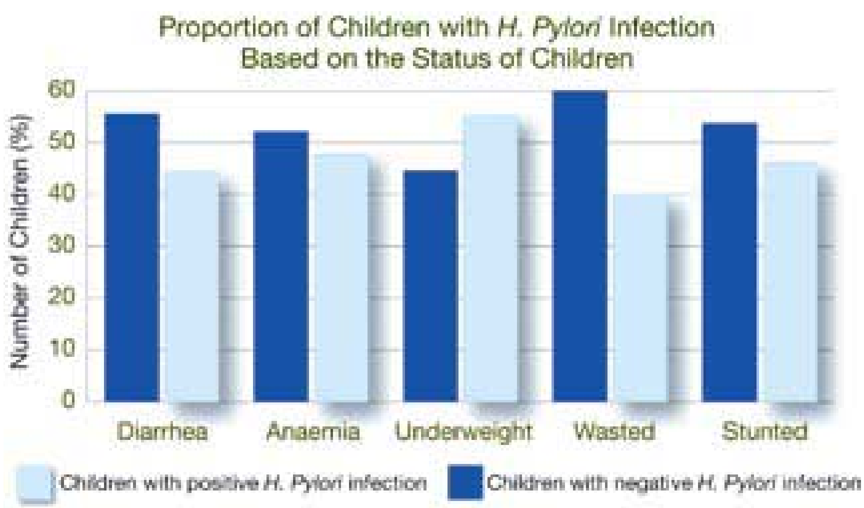
Carla Fjeld/IAEA

Assessing Interactions: Pollution and Infection

Nutritional status is not only determined by the quality and quantity of food consumed. Nutrition and pollution are interconnected: pollutants in the environment may deteriorate the nutritional status of populations; and poor nutritional status may increase the health risks posed by pollutants. To study this, a new CRP has been initiated in 11 countries (Bangladesh, Brazil, Chile, China, India, Kenya, Republic of Korea, Morocco, Peru, Sweden, and Viet Nam) to assess the effects of mercury and lead pollutants on the metabolism of key micronutrients.

Parasitic infestations and the spread of communicable diseases are more prevalent in malnourished populations.

Nutrient deficiencies impair the functioning of the immune system, which can lead to dramatically higher risk of infection. Faecal pathogens often cause diarrhoea, which then causes food and nutrients to be poorly absorbed by the body. Among the Agency's priority activities are projects on the prevalence of infection with the bacteria *Helicobacter pylori (Hp)* — linked to chronic malnutrition and diarrhoea syndrome in infants or children — and the impact of nutrition on infection by the Human Immunodeficiency Virus (HIV).



Results from Indonesia show the prevalence of H. pylori *infection among children suffering the consequences of malnutrition. IAEA Project: INS-11081*

Operational Sequence of ^{13}C–Breath Test

Intake of ^{13}C-labelled urea together with a test meal.

30 minutes later:

H. pylori negative !!
No enzymatic reaction, little $^{13}CO_2$ in breath.

H. pylori positive !!
Hp cleaved urea to from $^{13}CO_2$ which reaches breath via blood circulation.

1. Blow up the first breath bag
2. Drink ^{13}C-labelled test liquid and wait for 30 minutes
3. Blow up the second breath bag
4. Measurement

Figure credit: H. Fischer, K. Wetzel/FAN-GmbH

The ^{13}C-urea breath test uses a stable isotope of carbon (^{13}C) to detect *H. pylori* infection. The IAEA is transferring this test through an on-going CRP to study the prevalence of *Hp* infection in those at risk of early childhood malnourishment and diarrhoeal death.

Poor nutrition increases the risk of HIV infection and the progression of the disease. Undernourished people are not only more susceptible to HIV infection, they also develop AIDS more quickly once infected. As the disease progresses and becomes more serious, dramatic weight loss occurs. The IAEA is using isotope-based techniques to assess nutrition intervention programmes in 10 African countries (Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, Senegal, South Africa, United Republic of Tanzania, Uganda, and Zambia). The regional project is also monitoring participants' body composition to provide early warning of the need for nutritional intervention.

Future Directions

Good nutrition is vital to good health and a sustainable future. To achieve the goal set by the World Food Summit to halve hunger and malnutrition by 2015, effective programmes and a sustained commitment by governments, non-governmental and international organizations, and the private sector will be required. Nuclear science is being used by more and more countries to evaluate the effectiveness of nutritional interventions and can help guide the development of sound nutritional policy. For its part, the IAEA will continue to support innovative uses of nuclear techniques, in areas where they have been proven successful — alleviating micronutrient deficiencies, managing energy intake, and assessing nutritional interactions with pollution and infection — and beyond.

— Investigate nutritional and other factors that contribute to poor development of the foetus.

— Assess the impact of ageing on energy and nutrient metabolism.

— Study calcium metabolism in the elderly and its effect on osteoporosis.

PhotoDisc

Around the globe, United Nations agencies are working to improve human nutrition — one of the cornerstones to good health. The International Atomic Energy Agency (IAEA) is one such agency, offering technical solutions to improve nutrition monitoring techniques and identify effective strategies for nutrition intervention schemes, through the use of nuclear and isotopic techniques. These techniques, now considered among the best methods for studying the uptake and bioavailability of important nutrients, are being used in developing countries as tools to measure the success of their programmes against malnutrition.

The IAEA sub-programme on nutrition and effects of contaminants on human health uses nuclear and isotopic techniques to address two issues:

- **applied human nutrition assessment and research, and**
- **the study of contaminants affecting human health.**

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