Review Article

Nuclear and isotopic techniques applied to supporting nutritional studies in East Asia and Pacific Countries: IAEA's contributions over 20 years

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The world's scientific community has recognized that isotopic techniques play a vital role in monitoring the effectiveness of nutrition intervention by providing precise data on absorption, bioavailablity and interaction of various micronutrients in a cost effective manner. The International Atomic Energy Agency (IAEA) has been supporting many such health related studies in Member States from developing countries using nuclear and isotopic methods for over 20 years. This report documents the Agency's support for a variety of projects in East Asia and Pacific countries to assess body composition, total energy expenditure, nutrient intake, osteoporosis, infection, vitamin and mineral bioavailability as well as food composition. The IAEA spent a total of US$10,302,356 through Coordinated Research Projects (CRP) and Technical Cooperation Projects (TCP) over the past 20 years. Out of this only US$2,732,802, or 26.5% was used by the East Asia and Pacific countries. While the participation of East Asia and Pacific countries was strong in CRPs and moderate in regional TCPs, they did not participate in national TCPs at all. The non-participation under national TCPs is a serious deficiency when compared with Latin American and African regions and therefore, more participation from the East Asia and Pacific countries in national TCPs is strongly encouraged in the future.

Key Words: IAEA, Nuclear and isotopic techniques, nutrition studies, East Asia and Pacific countries

Introduction

The nutrition problems in the East Asia and Pacific where more than 50% of the world population resides with a poor economic situation are responsible for millions of deaths in this region. According to the United Nations Sub-Committee on Nutrition 2000,[1] one in five newborn infants in South Central Asia is affected with low birthweight at term and this fetal undernutrition will be linked to sufferings by chronic diseases in their adulthood. This is the most startling manifestation of the intergenerational transmission of undernutrition.[1] South Central Asia is the worst affected region, with 44% or 79 million children being underweight. In addition to these underweight problems, micronutrient deficiencies of iron, iodine and vitamin A are the most prevalent nutrition problems in this area. Anaemia prevalence is as high as 75% in South Central Asia.[1]

Nuclear and isotopic techniques used in human nutrition studies

Applications of nuclear and isotope techniques in nutritional sciences are progressing very rapidly in key areas of nutrition and health such as assessment of human body composition, total energy expenditure, nutrient intake, osteoporosis, vitamin and mineral bioavailability studies as well as detection of infection and analysis of foods (including food fortification) in developing countries.[2] Thus, stable isotope techniques are being used effectively by food industry for developing nutrient-fortified food products, by governmental and international institutions for designing food fortification programs, and by public health authorities for establishing reliable dietary recommendations for intake of inorganic nutrients.[3]

There are two forms of isotopic tracers: radioactive and stable. Radioactive isotopes can be detected via their radiation. However, the risk of radiation related health effects has over time dampened the use of radiotracers in human subjects. Stable isotopes on the other hand are invaluable since there is virtually no health risk involved in their use. They are therefore preferred for studies in humans, especially in infants and pregnant women.

Many naturally occurring elements exist as a mixture of two or more stable non-radioactive isotopic forms. Heavy stable isotopes like ^{54}Fe, ^{56}Fe, ^{57}Fe, ^{58}Fe, ^{64}Zn, ^{66}Zn, ^{68}Zn, ^{70}Zn and light stable isotopes like ^{1}H, ^{2}H, ^{13}C, ^{12}C, ^{15}N, ^{14}N, ^{16}O, ^{17}O, ^{18}O are mostly used in human nutrition studies.[2] The stable isotopes can be administered either orally (water,

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food, etc) or intravenously (in required form). Depending on the rate of absorption of the administered compound, the stable isotopes will be incorporated into metabolic products, such as body water, urea or CO_2. These can be sampled in saliva, milk, breath, urine, and stool. The ratio of minor to major isotopes can then be determined by isotope ratio mass spectroscopy, infrared absorption or emission spectroscopy.[2] In the past 20 years there has been great improvements in computer and mass-spectrometer technology that has helped to open up even greater possibilities in the understanding of human metabolism.[4] The nuclear techniques which may help in combating nutrition-related disorders in all stages of human life are summarised in Table 1.[5]

The objective of this review is (i) to illustrate how stable isotopic techniques could be applied to nutritional studies in developing countries, (ii) to describe the activities of the International Atomic Energy Agency (IAEA) in supporting nutritional studies during the last 20 years (1983 – 2003), and (iii) to review the financial resources of IAEA which can support nutritional studies to provide up-to-date knowledge about the IAEA nutritional studies in order to encourage growing participation of the East Asia and Pacific countries' nutritionists and future governments.

The IAEA progamme on human nutrition studies

The IAEA's main objective is to promote safe, secure and peaceful development of nuclear technologies. The use of isotopes or nuclear related techniques to evaluate human nutritional status and the nutritional quality of foods is within the IAEA's program of the human health area.[6] The IAEA is a partner in addressing nutrition and health problems in more than 50 countries in collaboration with member states counterparts, other United Nations Organisations and donors. The IAEA activities in nutrition are aimed at assessing nutritional status as well as the nutritional quality of foods within the context of national development programmes.

The IAEA offers technical support to evaluate the efficacy of fortified foods, food supplementation programs and other interventions aimed at fighting many forms of malnutrition found throughout the world.

For many years now, the IAEA's activities in research and technical co-operation include a strong emphasis on the application of nuclear and related isotopic techniques as tools to solve nutritional problems prevalent in developing countries. Indeed, the world's scientific community has recognized that isotopic techniques can play a vital role to check effectiveness of nutrition intervention programmes by providing precise data regarding absorption, bioavailablity and interaction of various micronutrients in a cost effective manner.

The IAEA tools used for project implementation

The IAEA is contributing to the alleviation of malnutrition through strengthening the application of nuclear and isotopic techniques in human nutrition[2,7,8] by offering technical solutions to improve monitoring techniques and identifying effective strategies in nutrition intervention programs through its Coordinated Research Projects (CRP) and Technical Cooperation Projects (TCP).[2]

CRP is a mechanism by which groups of countries are brought together to work on a well-defined research topic, and the mean duration of a CRP is 3 years. A modest annual funding to developing countries is made available by the IAEA, mainly for sample collection, analysis, and supplies. As a crucial part of CRP, collaboration between scientists from developing and industrialized countries is stimulated and exchanges of information are encouraged through participation at the research coordination meetings (RCM) funded by the IAEA.

Recently, a new type of CRP has been introduced which is dedicated to supporting PhD students. T-CRP (thematic – CRP) is increasing the scope of a normal CRP for capacity building in developing countries. Pairs of countries (developed and developing countries) are stimulated to work together. This new CRP is for promoting postgraduate training in the country of origin with a possibility of training in a developed country. It will have a longer duration of up to 4-5 years, and has an increased level of funding through traditional CRPs.

TCPs are substantially large national projects contributing to socio-economic development of a given Member State. They are programmed for 2-4 years, and if on a regional basis, they are called regional projects with multiple participants. The TC projects should have a strong Government support of National Nutrition Programs. The main objective of TCP is to transfer mature nuclear and related techniques to solve specific nutrition problems but at the same time building up scientific and technical capacity in the country.

Table 1. Nuclear and isotopic techniques in nutritional sciences

Life Stage	Nutritional Disorders	Applicable Nuclear Techniques
Embryo/ Fetus	Intrauterine growth Retardation; Low birth weight; Protein-Energy Malnutrition; Folate, Iodine, Vitamin A, Iron Deficiencies.	• RIA† (ferritin, folate, T_3, T_4, TSH and other hormones) • Doubly labelled water $^2H_2{}^{18}O$ (body composition, energy expenditure) • Deuterium labelled water ^2H_2O (breast milk intake, body composition) • Stable isotopes (micronutrients, e.g ^{57}Fe, ^{67}Zn) • ^{13}C and ^{15}N labeled substrates (macronutrients, Helicobacter pylori) • DEXA‡, CT (bone density, body composition)
Neonate		
Infant & Young Child		
Adolescent	Protein-Energy Malnutrition ; Iodine, Iron, Folate, Calcium, Deficiency; Obesity; Cancer; HIV/AIDS; Osteoporosis	
Pregnant & Lactating Mothers		
Adults		
Elderly		

† RIA = Radioimmunoassay; TSH = Thyroid Stimulating Hormone; T_4 = Thyroxin

‡ DEXA = Dual Energy X-Ray Absorptiometry; CT = Computer Tomography, Source: Modified from WHO/NHD/99.9[4]

The implementation strategy for TC projects has to consider several criterias for approval. Nutrition intervention programs need to include evaluation and monitoring. There must be direct links between TC counterparts and the public health agencies that can absorb the recommendations resulting from the project and use them to modify interventions if needed.

One of the advantages of nuclear techniques over conventional methodology of evaluation is the response time to the impact evaluation and the number of subjects required. With this, the use of nuclear techniques can increase the efficiency of the evaluation of such programs in a cost effective manner. In nutrition interventions, a multidisci-plinary approach is required and partnerships with social authorities are important for successful evaluation of the program. The IAEA supports infrastructure (equipment and supplies), workshops, subcontracts for technical help, experts, fellowships and scientific visits.[2]

Besides the regular projects shown in Tables 2 and 3, some of the IAEA nutrition related extended activities are as follows:

- Setting up concepts in Nutrition Metrology (the science of measurements) related to nutritional studies such as food composition, food intake to ensure the most accurate results from an analytical effort, energy intake and expenditure, body composition and measurements.
- Interactions with other international organizations such as FAO, WHO, UNICEF and Asian Development Bank in an effort to support projects of mutual interest.
- Dissemination of the IAEA's efforts through the United Nations Standing Committee on Nutrition (UN-SCN) to share relevant information on world wide nutritional problems.
- Updating the data base on 'Reference Materials for Nutrition and Environmental studies', to assist laboratories in Asia and Pacific countries to have an easy access to obtain certified materials to assure quality control of its laboratories measurements.

Nuclear methods: light and heavy stable isotopes in IAEA Projects

Some examples of IAEA nuclear and stable isotope techniques used in human nutrition studies[9] are based on the use of light and heavy isotopes of various elements.

Light element stable isotopes

Deuterium or ^{18}O labeled water can be used to measure:

a) Lean Body Mass (Body Composition)

A trace dose of water labelled with ^{2}H or ^{18}O is administered and allowed to equilibrate for 4-6 hours. Isotope enrichment in urine or saliva samples is measured to calculate body water volume. Total body water is used to quantify fat-free mass. Body composition is calculated from measured body water and the hydration coefficient of fat-free mass. The amount of fat (adipose) tissue is calculated as the difference between total body weight and fat-free mass (lean body mass). An increasing problem with obesity is being recognized in countries considered to be in "nutrition transition". As a result from the project in Chile**,** it was recognized that it is necessary to reduce the energy intake of children in order to prevent obesity.[10] On the other hand, lean body mass can also be considered a valuable indicator to monitor body wasting in HIV/AIDS patients, which shows a decrease in body lean mass and an increase in energy expenditure and protein catabolism when compared to HIV negative patients.

b) Breast milk intake

The mother is given a dose of ^{2}H- or ^{18}O-labelled water, which mixes with the body water pool and is transferred to the baby via the breast milk. By collecting samples of the mother's saliva or milk and the baby's saliva or urine, the breast milk intake of the baby can be calculated. For example, the IAEA gave technical support to a community nutrition programme in Senegal. The results indicated that breast milk output was not influenced by supplementation. In contrast, the lactose, total protein and zinc contents of milk increased significantly in supplemented mothers.[11]

c) Doubly labelled water method

Doubly labelled water method is used for estimation of total energy expenditure to determine the caloric expenditure of people in their normal environment. It is accurate and can be applied under field conditions. After administration of a simple dose of doubly labelled water $^{2}H_{2}{}^{18}O$ both isotopes equilibrate with total body water and are eliminated differentially in body fluids over a period of days. Deute-rium (^{2}H) leaves the body as water and ^{18}O leaves it as water and CO_2. Thus, the difference in the rate of loss of the two isotopes (^{18}O and ^{2}H) is used to calculate CO_2 production of the subject, which in turn is used to calculate energy expenditure. It may be mentioned that the FAO/WHO/UNU expert committee convened during 2001 to establish new energy recommendations using the results of investigations on energy expenditure of young children in Cuba. Prior to this project no data existed from Latin America to provide a scientific basis to formulate food programmes suited to the local conditions.

d) ^{13}C-urea breath test

^{13}C-urea breath test is used to detect *Helicobacter pylori* infection in humans. Breath is collected for a base value before a ^{13}C-labelled urea is administered. The enzyme urease of *H. pylori* breaks down the urea into ammonium and labelled bicarbonate. The latter compound will be metabolised by the person into carbon dioxide and expired. After 20-30 minutes a second breath sample is collected and measured for the label.

Heavy element stable isotopes

Fe and Zn are frequently used for trace element bioavailability studies. The uptake and metabolism of labelled micronutrients can be traced *in vivo*. In fact, stable isotopes provide the only way of measuring the uptake and bioavailability of trace elements in humans. For example, as a result of the IAEA's activities in Chile the government modified its policy for pre-school children nutrition intervention programmes (coverage of ~1.3 million). The study had shown that anaemia was reduced from 30% to less than 5% within a year after using foods fortified in iron and zinc in a sample of 300 children.[2] It is widely used to determine the effectiveness of fortification and supple-mentation programmes in several developing countries.

Table 2. CRP list of IAEA Nutrition studies during 1983 - 2003

Co-ordinated Research Projects (CRP)	Project Number	Country	Starting Year
Completed:			
Dietary intake of trace elements	E4.30.01	Turkey, Spain, Brazil, Iraq, Sudan, *Thailand†, China*, Italy, Sweden, USA, Canada, Yugoslavia, Australia, Finland	1983
Toxic elements in foodstuffs (RCA)	E4.30.02	Jamaica, *Bangladesh, Thailand*, *Pakistan*, Australia, *China, Malaysia, India, Japan, Indonesia*, Netherlands	1985
Applications of stable isotope tracers	E4.30.03	*China*, Germany, Ghana, Papua New Guinea, Romania, Australia, *India, Malaysia,* Mexico, Uruguay, *Goa,* Italy, Senegal, Nigeria, UK, US	1988
Bioavailability of Fe & Zn	E4.30.04	Chile, *India, Myanmar, Pakistan*, Peru, *Philippines,* Poland, *Sri Lanka*, Venezuela, UK, US	1990
Amino acids, protein, energy metabolism	E4.30.05	*Bangladesh*, Bolivia, Guatemala, *India, Pakistan, Philippines*	1992
Osteoporosis	E4.30.06	Brazil, Canada, Chile, *China*, Croatia, Hungary, *Philippines*, Russia, *Singapore*, S. Africa, Turkey	1994
Vitamin A	E4.30.07	*China, India*, Israel, Peru, *Philippines,* S. Africa, *Thailand*	1995
Reference Asian Man	E4.30.08	*Bangladesh, China, India, Indonesia*, *Japan, Korea, Malaysia, Pakistan*, *Philippines, Vietnam*	1995
Prevention of Stunting	E4.30.09	Argentina, Brazil, Chile, Mexico, *Pakistan*, Peru, Venezuela	1996
Infant Growth Monitoring (Collaboration with WHO)	E4.30.10	*Bangladesh*, Brazil, Chile, *Pakistan,* UK, USA	1999
Prevention of Degenerative Diseases (Obesity, Non-insulin Dependent Diabetes and Coronary Heart Disease) in Ageing	E4.30.11	Brazil, Chile, *China,* Cuba, *India,* Jamaica, Mexico, Nigeria	1999
Active:			
H. Pylori Infectionin Early Childhood	E4.30.12	Argentina, *Bangladesh*, Belgium, Benin, Chile, *India, Indonesia,* Mexico, *Pakistan*, Senegal	1999
Nutrition-Pollution Interactions and their Impact	E4.30.14	*Bangladesh,* Brazil, Chile, *China, India,* Kenya, *Korea,* Morocco, Peru, Sweden, *Vietnam*	2001
Thematic Co-ordinated Research Projects (T-CRPs) for capacity development in Developing Countries			
Micronutrient Status and Interaction	E4.30.13	*Bangladesh*, Ghana, *India, Indonesia, Pakistan, Sri Lanka, Thailand*	2001

†Asian countries are in *italicised* letters

Nuclear and related methods

a) Neutron Activation Analysis (NAA)

NAA is very effective in analysis of foods due to its exceptional sensitivity and multielement determination capability for several trace elements. Inductively Couples Plasma Mass Spectrometry (ICP-MS) also offers multi-element determinations. Application of NAA-related methods is particularly attractive for developing countries since many research reactors are available to provide the needed neutron source. In Libya, for example, under an IAEA project this nuclear method is used to determine food nutritional values and dietary intake of minor and trace elements.[2]

b) Dual Energy X-ray Absorptiometry (DEXA) DEXA can be used for bone mineral density studies. Low energy x-rays are passed through the bones to measure the mineral (calcium) content of the bones and the precision of DEXA is very high and the data can be standardised for age, weight, height and ethnic status. The IAEA has applied this for a CRP on osteoporosis to establish a model for bone mineral density measurements on a global scale.[12]

Table 3. List of IAEA supported Regional TC Projects on Nutrition Studies during 1994 – 2003

Regional Projects	Project Number	Country	Starting Year
Completed:			
Measuring the effectiveness of multinutrient supplementation	RAS/7/010	*China*† *Indonesia, Malaysia, Pakistan, Philippines, Thailand, Vietnam*	1999
Active:			
Evaluate nutrition intervention programs	RLA/7/008	Chile, Cuba, Brazil, Mexico	2002
Early diagnosis of *Helicobacter pylori* infection (ARCAL LIV)	RLA/6/042	Argentina, Bolivia, Brazil, Chile, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Mexico, Panama, Peru, Venezuela	2001
Diagnosing osteoporosis (RCA)	RAS/7/012	*India, China(Hong Kong), Singapore, Thailand, Viet Nam, Philippine*	2003
Monitoring food fortification program	RAS/7/014	*China, Indonesia, Pakistan Thailand, Vietnam*	2003
Assess nutrition intervention related to HIV/AIDS in Africa	RAF/7/006	Ghana, Senegal, South Africa,	2003

†Asian countries are in *italicised* letters

Table 4. List of IAEA supported Country TC Projects on Nutrition Studies during 1994 – 2003.

Country Projects	Project Number	Country	Starting year
Completed:			
Isotopes in Nutrition Studies	CHI/7/007	Chile	1997
Micromineral interaction in Vulnerable groups	CHI/7/008	Chile	2002
Evaluating supplementary infant feeding practices	ETH/7/004	Ethiopia	
Improve Child Nutrition	PER/7/003	Peru	1994
Dietary studies in Portugal	POR/7/002	Portugal	1994
Isotope evaluation of community nutrition program	SEN/7/002	Senegal	1999
Evaluation of Community program	SEN/7/003	Senegal	2003
Investigating micronutrient deficiency	SIL/7/002	Sierra Leone	1995
Improvement of nutrition & diagnosis	SRL/7/004	Sri Lanka	2001
Active:			
Evaluating Zn, Vit. A as supplements in treatment of Malaria	BKF/7/002	Burkina Fasso	2003
Evaluate impact of multinutrient supplements on pregnancy outcomes	EGY/7/003	Egypt	2003
Evaluation of complementary feeding program	GHA/7/003	Ghana	2003
Improving nutritional status of children and women	MAG/7/003	Madagascar	2003
Trace element methods for studies workplace monitoring	NIR/7/003	Nigeria	1999
Monitoring food fortification program	SAF/7/003	South Africa	2003
Food Supplementation strategy for women in rural areas	SEN/7/004	Senegal	2003

Summary of CRP, T-CRP and TCP, 1983-2003

The IAEA focussed on analytical quality assurance as a whole in the '80's introducing many certified reference materials (CRMs) e.g total diet material, milk powder, animal muscle, among others. This was followed by the development of a user-friendly natural matrix RM database (http://www.iaea.or.at/progrmmes/hahunet/e4/index.html) exclusively for environmental, biological

and food matrix materials. The next step was harmonisation of relevant parameters such as project design, sampling and sample processing procedures, streamlined approaches for validation of methods and data acquisition and strategies for data treatment implemented through the reference laboratory concept. These measures have resulted in *metrological* improvements in many areas of human physiology. For example, harmonised measurements of bone mineral densities in subjects belonging to 11 countries using dual energy X-ray absorptiometry have been documented in a recent CRP on osteoporosis.[12] Similarly, a CRP on aging and obesity has identified systematic errors of over 10% in dietary energy intake by applying the doubly labelled water technique contributing to FAO/WHO/UNU Expert Committee deliberations for establishing new energy recommendations.[13]

Tables 2, 3 and 4 show lists of CRP and TCP of the IAEA in nutritional studies during the last 20 years and the Asian countries involved in CRP and TCP are shown in italicised letters. There were 14 CRPs since 1983 and the topic, project number, participating countries and starting year of each CRP are shown in Table 2. The number of Asian countries participating in each CRP varied from one to 10 countries.

Three CRPs out of 14 are on-going (active) and 11 CRPs are completed as of March 2003. Table 3 summarizes the topics, project number, participating countries and the starting year of one completed and five active regional TC projects. Out of a total of 16 national TC projects since 1994, 9 of them are completed and seven of them are still active as shown in Table 4.

IAEA-supported nutritional studies in East Asia and Pacific countries

In the early 1980's the topics of the CRPs focused mainly on trace elements studies. In the '90's the focus was on amino acid and protein metabolism, osteoporosis, vitamin A and infant growth monitoring studies followed by prevention of degenerative diseases and *H. Pylori* infection studies in the 2000's. The T-CRP for capacity development program is supporting 6 Asian countries to carry out graduate students in the nutrition field.

There are one completed and two active Asian regional TC projects. For the most recently completed Asian regional TC project (RAS 7010), the topic was on measuring effectiveness of multinutrient supplementation, and the two active projects are on diagnosing osteoporosis (RAS 7012) and monitoring food fortification programs (RAS 7014). In 1999 the first regional TC project dealt with measuring effectiveness of multinutrient supplementation covering China, Indonesia, Malaysia, Pakistan, Philippines, Thailand and Vietnam.

Some examples of IAEA human nutrition projects in the East Asia and Pacific countries based on the use of stable isotopes methodology are as follows:

Micronutrient malnutrition

In 1995, as a result of the CRP studies on vitaminin A status (E.4.30.07), the IAEA assisted the countries to gain experience in using the deuterated-retinol-dilution (DRD) procedure in school children in the Philippines with low serum retinol concentration who showed significant improvement in total body vitamin A stores following intake of carotene-rich foods. The stable isotope techniques could also be employed to quantify the effect of several other factors that could influence the absorption of carotenoids.

As a result of this, CRP based on the 3 days DRD techniques, studied the effect of vitamin A status of the school children on the bioconversion of plant carotenoids to vitamin A. The following conclusions were reached:

i) The three days DRD could detect changes in the body pool size of vitamin A.

ii) Bioconversion of plant carotenoids to vitamin A varied inversely with vitamin A status.

iii) An improvement occurred in vitamin A status after dietary intervention.[9]

The T-CRP (E4.30.13) project in Indonesia presently uses isotope techniques to assess the effect of dietary fat and zinc status on beta-carotenes bioavailability and bioconversion into vitamin A in children and lactating women. Isotope dilution techniques therefore have potential to evaluate the impact of vitamin A/retinol and provitamin A/carotenoids intervention programs.

The East Asia and Pacific region TC project (RAS 7010) started in 1999 with the objective to ensure the efficacy of nutrition intervention schemes with the help of stable isotopic techniques to assess Fe and Zn bioavailability to measure the effectiveness of multinutrient supplementation. The project has yielded some very practical results. China, Indonesia, Malaysia, Pakistan, Philippines, Thailand and Viet Nam participated in this study.

The investigations carried out in Indonesia using stable isotopes to measure the effectiveness of fortified wheat flour have attracted the co-sponsorship of UNICEF. The Indonesian experience is also being used by other participating countries, such as China and Pakistan in performing their studies to advise their national Governments and policy makers in improving or formulating their nutrition policies. In China, anaemic children who were given iron-fortified sauce, returned to normal blood iron levels within a period of three months. The project in Indonesia reported that 35% of their preschool children were underweight and 50% were micro-nutrient deficient including Fe and Zn.[10] Technical and scientific input by the IAEA national food fortification program has addressed the problem of Fe and Zn, through the wheat flour fortification initiative, which will benefit both children and adults. The study in Indonesia demonstrated that iron sulfate from a fortified diet is well absorbed (15%), however, when zinc sulfate is also added this mixture reduces the bioavailability of iron sulfate. In contrast, zinc oxide did not affect iron absorption.[10]

According to this TC project, anaemia was prevalent among women and children in Indonesia (50% of preschool children) and China (30%). This project aimed at evaluating Fe status in school children consuming iron-fortified sauce during three months. This work came out with results demonstrating that anaemic children have restored their blood iron to normal levels.[10]

Also, as a part of this TCP (RAS7010), it was possible to have isotope technique application training courses in seven Asian countries (China, Malaysia, Philippines,

Vietnam, Indonesia, Pakistan and Thailand) at Bangkok, Thailand in 1999.

Body composition studies

There were 2 CRPs for body composition studies in the East Asia and Pacific countries. One CRP (E4.30.09) was on prevention of stunting and this was done in the field studies of Pakistan infants[14,15] since 1999, where the deuterium dilution method was established and applied to measure breast-milk intake and compared with the test weighing method. The other CRP was on infant growth-monitoring (E4.30.10) in collaboration with the WHO Growth Monitoring Programme which also started in 1999 providing growth reference data in Bangladesh and Pakistan.[16]

Infection

A CRP (E4.30.12) on *H. Pylori* infection was carried out with the participation of India, Bangladesh, Pakistan and Indonesia along with a number of countries in Africa and Latin America. Persistent diarrhoea accounts for over 47% of infant diarrhoeal deaths in India and 26% in Bangladesh. Stable isotope techniques are the best and most cost effective modes of diagnosis of *H. pylori* infection. Through this CRP for facilitating diagnosis and preventive interventions, 1300 children from Bangladesh, India and Pakistan and Benin have been investigated.[17] Isotopic techniques using ^{13}C-labelled substrate breath tests for bacterial colonization and digestion and absorption of nutrients (lactose, amino acids and triglycerides).

Radiological safety

In 1995, CRP (E4.30.08) enhance their ability to resolve national problems of radiological protection, as well as to facilitate development of the characteristics of a reference Asian man, the primary goal of this project.

Improved reference values have been derived for a number of additional elements (Cs, I, Sr, Th, U) and other trace elements of secondary importance, in staple foods and total diets and in tissues such as thyroid, bone, liver and muscle. Nuclear and related techniques, i.e. neutron activation analysis and inductively-coupled plasma mass spectrometry, together with complementary methods such as inductively-coupled plasma atomic emission spectrophotometry and atomic absorption spectrometry were used to perform chemical analysis. Since the project involved a group of countries working under different conditions, attention was paid to establish a reasonable mechanism to ensure accuracy and comparability of the analytical results generated for their quality assurance aspects as previously reported.[18]

Prevention of degenerative diseases

CRP (E4.30.11) on prevention of degenerative diseases in aging was started in 1999 to define the magnitude of the problem of obesity and non-insulin dependant diabetes mellitus (NIDDM) in developing countries, to identify the vulnerable groups at increased risk, and to attempt to describe the metabolic and physiological mechanisms underlying this phenomenon. These comparative international studies of obesity and NIDDM looked at various aspects of obesity from eight countries. China participated to study levels of patterns of physical activity of older adults in comparison to their dietary intake.

Overweight and obese groups in China had significantly greater BMI, waist, hip, waist/hip ratio, and percent body fat than the normal weight group. Their total energy and fat intakes were greater than those of the normal weight group, while they expended much less energy. The obese had a significantly higher risk of hypertension, and had higher fasting insulin and leptin levels than the normal weight group.[19]

India did a study on body compositional changes and the role of inflammatory cytokines on impaired glucose tolerance study and the study concluded that measurement of body fat and its central distribution by appropriate isotopic and other methods should form an essential part of further studies on insulin resistance and cardiovascular disease risk in South Asians.[20]

Also, New Zealand researchers compared the energy expenditures of Maori (Pacific Island) with New Zealanders of European descent. They found that increased body fat content and central obesity were associated with measurements of glucose, insulin, lipids and leptin indicating an increased risk of NIDDM. Central obesity was negatively associated with dietary fibre intake. This CRP concluded that it provided an opportunity to use standardized protocols for body composition and physical activity measurements as risk factors for chronic disease in several developing countries despite variations in age, ethnicity, and geographic locations of the study populations.[21]

Nutritional and health related environmental studies (NAHRES) publications

Nutritional and health related environmental studies section documents reports of its main activities e.g. Consultant, CRP and RCM meetings and the list is shown in Table 5. From each CRP there was 1 to 7 NAHRES reports published. These are the written results of the CRP studies so that the information can be utilized as reference materials for future applications. Unfortunately, no written reports are available for TCPs on nutritional studies.

Table 5. List of NAHU Reports from the East Asian and Pacific Countries CRP & TC Projects during 1983 – 2003

CRP Project No.	NAHRES Report No.
E 43001	2, 8, 10
2	3, 23
3	4, 5, 7
4	11, 20, 34
5	15, 21, 30, 41
6	14, 28, 31, 39, 40, 51, 67
7	25, 32
8	38, 54
9	44, 48
10	55
11	47
12	56

Table 6. Financial summary of CRP nutrition projects supported by the IAEA during 1983 – 2003

Project No.	Total funds used (US$)	Fund Used by Asian Countries (US$)	No. of countries using funds	No. of Asian countries Using funds
E4.30.01	169,850	39,500	13	2
2	127,300	122,300	11	9
3	162,500	18,000	14	3
4	156,000	77,500	9	5
5	256,600	111,500	6	4
6	280,500	85,000	11	3
7	377,200	177,200	7	4
8	170,500	170,500	10	10
9	153,600	14,000	7	1
10	80,500	32,500	4	2
11	286,500	68,000	8	2
12	185,500	70,000	10	4
13	175,000	125,000	9	6
14	90,000	49,000	9	4
Total	*2,671,550*	*1,160,000*		

Financial resources in support of Nahres nutritional projects

Table 6 shows a financial summary of CRPs on Nutrition supported by the IAEA since 1983. The funds available for a project ranged from US$80,500 to 377,200. The total CRP contract funds supported were US$ 2,671,550 and the fraction of the funds used by the East Asia and Pacific countries were US$ 1,160,000 (43.4%).

Table 7 and 8 show a financial summary of regional and country TC projects fund, respectively, supported by the IAEA since 1994. The total TC contract funds were US$7,630,806, out of which the regional share was US$3,985,992 (52.2%) and the country share was US$3,644,814 (47.8%). From the total TC project fund of US$7,630,806, the East Asia and Pacific countries used only 20.6%. No national TC projects were undertaken. The total IAEA funds used for nutrition studies by both CRP and TCP during the last 20 years were US$ 10,302,356 and out of this, US$ 2,732,802 (26.5%) were used by the East Asia and Pacific countries. This financial analysis summarises that the East Asia and Pacific countries were supported by 43.4% of the total CRP fund but only 20.6% of the IAEA total TC Fund. Noteworthy to mention, the Asian countries are not very active in participating TC projects compared with CRPs, while in the TC area their participation is concentrated in regional TC projects.

Table 7. Financial Summary of IAEA supported Regional TC Nutrition Projects during 1994 - 2003

Regions	Project Number	Amount used (US$)	Year started
Completed:			
Asia and Pacific	RAS 7010	525,468	1999
Active:			
Latin Am	RLA 7008	1,162,380	1999
Latin Am	RLA 6042	404,410	2001
Asia and Pacific	RAS 7012	1,017,234	2003
Asia and Pacific	RAS 7014	30,100	2003
Africa	RAF 7006	846,400	2003
	SubTotal	*3,985,992*	

Conclusions

Surprisingly, it is observed from this review that there was no single national TC project from the East Asia and Pacific countries during the period 1983 – 2003. Therefore, it is recommended that communities from this region should consider higher participation in IAEA TCPs under national projects. Through many nutritional studies supported by IAEA in the last 20 years it was proven that nuclear and stable isotope techniques were applied to strengthen technical solutions to alleviate major nutrition problems in Asian and Pacific regions.

It is recommended to continue national development strategies for improvement of nutrition by food fortification, supplementation and where possible dietary diversification and biofortification. Among these solutions, approaches based on food fortification and biofortification, are very practical in reaching large segments of a given population. From a technology point of view, nuclear and isotopic techniques are at an advanced stage to provide the measurement capabilities in support of food composition and bioavailability studies and evaluation of field trials related to food fortification and biofortification. The East Asia and Pacific countries facing challenges to overcome the malnutrition problems should utilize various helpful avenues available at the IAEA human health division to find technical solutions to their projects of national relevance.

The future

One way to reduce malnutrition in East Asia and Pacific countries is to introduce multiple or single supplementation/fortification programs of a potential nutrient or diet interactions in the target population. Several East Asian countries have tried these nutrition improvement programs but the challenge is its sustainability and evaluation of effectiveness similar to the African countries.[5] Also fortified foods must be extensively tested in the developing phase to ensure the feasibility of manufactu-

Table 8. Financial Summary of IAEA supported Regional TC Nutrition Projects during 1994 - 2003

Country	Project Number	Amount used (US$)	Year started
Completed:			
Chile	CHI/7/007	396,127	1997
Chile	CHI/7/008	266,024	2002
Ethiopia	ETH/7/004	76,163	1999
Ghana	GHA/6/011	211,132	1999
Peru	PER/7/003	773,107	1994
Portugal	POR/7/002	140,388	1994
Senegal	SEN/7/002	42,896	1998
Senegal	SEN/7/003	265,743	2003
Sierra Leone	SIL/7/002	147,205	1995
Sri Lanka	SRL/7/004	270,287	1997
	Sub Total	*2,589,072*	
Active:			
Burkina Fasso	BKF/7/002	151,593	2003
Egypt	EGY/7/003	128,340	2003
Ghana	GHA/7/003	210,409	2003
Madagascar	MAG/7/003	162,630	2003
Nigeria	NIR/7/003	198,900	1999
Senegal	SEN/7/004	136,580	2003
South Africa	SAF/7/003	67,290	2003
	Subtotal	*1,055,742*	
	Total	*3,644,814*	
	Grand total	*7,630,806*	

ring and their acceptability to the consumer. This brings the isotopic techniques to the forefront, again. The new nutrition activities foreseen in the East Asia and Pacific countries are CRPs on IUGR (Intra Uterine Growth Restriction) and energy metabolism and physical activity. Among TCPs, bone health of the elderly and childhood obesity are seen as possibilities.

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