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Vital Nutrients

SUPPORTING LIFE, HEALTH, AND PRODUCTIVITY THROUGH IRON, IODINE, AND VITAMIN A NUTRITION

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COVER PHOTOGRAPH BY JOAN SULLIVAN

Introduction

Over the past few years, important new knowledge about the problem of micronutrient* deficiencies has completely changed the way we plan, implement, and evaluate activities designed to address such deficiencies.

- Micronutrients — previously recognized primarily as agents for preventing specific disorders such as blindness — have been found to save the lives of mothers and children, to stimulate mental development, to protect against infectious diseases, and to improve adult capacity for physical work.
- Activities aimed at improving micronutrient status can be incorporated into almost any kind of existing program that reaches infants and young children and their families.
- Many micronutrients occur widely in nature in edible forms; where they are not readily obtainable, synthetic or concentrated forms of micronutrients are available at relatively low costs.

Based on these facts, A.I.D., other bilateral donors, U.N. agencies such as WHO, UNICEF, the World Bank and FAO, and many developing countries are working hard to reach micronutrient-deficient vulnerable groups. This document provides a brief overview of recent studies on the effects of micronutrients, current knowledge on how and why micronutrient deficiencies occur, who is particularly at risk, interventions that work, and how professionals engaged in a broad range of programs can play a key role in preventing and controlling micronutrient deficiencies.

**Increasingly, vitamins and minerals essential for human growth and functioning are referred to as* micronutrients *(nutrients needed in very small amounts). Given the prevalence and significance of vitamin A, iron, and iodine deficiencies, the term micronutrient is often applied to these particular nutrients. Other nutrients such as calcium, zinc, vitamin C, the B vitamins, and others may prove to be critical as well.*

Micronutrients can dramatically affect overall health, child survival, productivity, and mental performance. . . The human and economic value of addressing micronutrient deficiencies far surpasses the cost of interventions. . .

Why Have Micronutrients Gained New Importance?

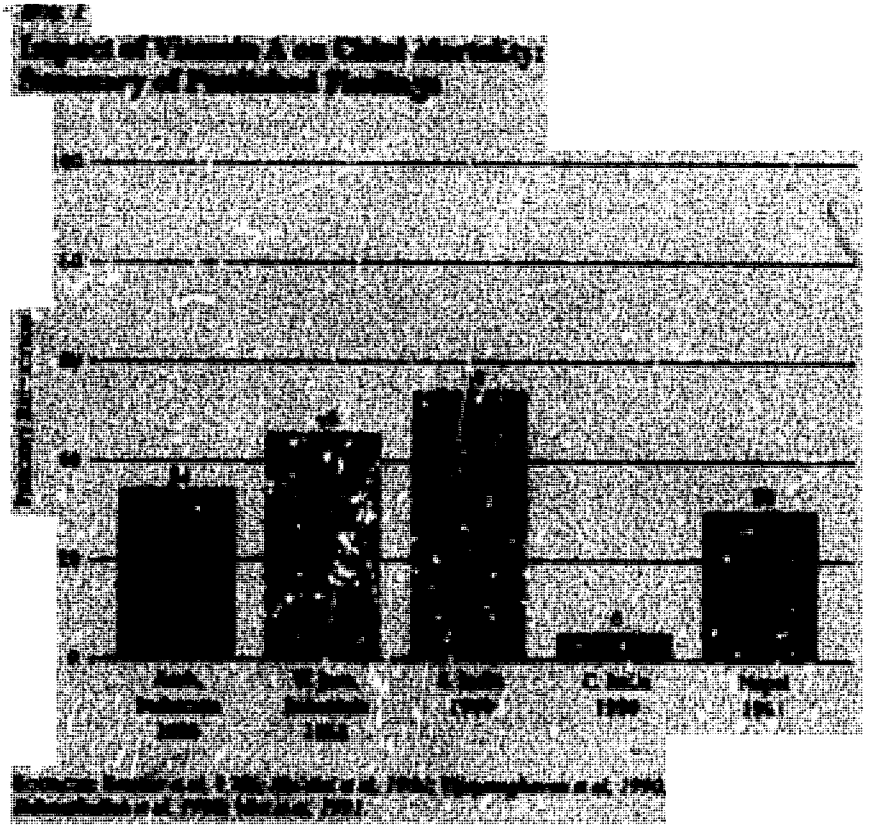
At the World Summit for Children held in New York in September 1990, political leaders from around the world endorsed the "Declaration on Children" and targeted the year 2000 for both the virtual elimination of vitamin A deficiency and iodine deficiency, and a one-third reduction in the number of women afflicted with iron-deficiency anemia. International agencies including A.I.D., WHO, UNICEF, FAO, and the World Bank, are exploring ways to respond fully to Declaration goals. Concerned that the international community is not adequately addressing micronutrient deficiencies, the U.S. Congress has in the past few years encouraged a review of micronutrient levels in food aid commodities and earmarked funds to expand programs for vitamin A and other micronutrients. The scientific basis for this interest lies in new research that shows that increased levels of micronutrient consumption can dramatically affect overall health, child survival, productivity, and mental performance. Some of these results can be achieved with less than a U.S. dollar per person expenditure, per year. Further, existing delivery systems can often be used. Despite the availability of technologies to solve micronutrient problems, approximately 1.5 billion people suffer from various micronutrient deficiencies worldwide. A resurgence of vitamin C, B vitamin group, and other deficiencies—once thought to have been eliminated—all further strengthen the case for a redoubling of efforts to achieve the micronutrient goals of the "Declaration for Children."

Micronutrients Can Save the Lives of Mothers and Children

In Vitamin A Supplementation Trials, Mortality Risk in Children Was Substantially Lower. In most developing-country settings, maintaining sufficient stores and circulating levels of vitamin A protects against the risk of death from such common childhood diseases as measles, diarrhea, and respiratory

infections. Vitamin A is required for proper maintenance and functioning of the immune system and is essential to ensure the integrity of the respiratory and digestive epithelia that protect children from acute infections. Five published community-based intervention trials in Asia measured the impact of vitamin A supplementation. The results of four studies showed strong, consistent, and statistically significant reductions in child death *(see Box 1)*.

- A study in Indonesia first reported that vitamin A supplementation may substantially reduce child mortality in populations with a high prevalence of mild and moderate vitamin A deficiency. In a randomized trial of high doses of vitamin A administered every six months to children aged one to six, villages in the Aceh province designated for vitamin A treatment experienced a 34 percent reduction in mortality compared with untreated villages. (Sommer et al., 1986)
- Preliminary results of a prospective, double-blind, placebo-controlled study that provided supplements every four months to a group in the Sarlahi district of Nepal show a 30 percent reduction in mortality among children under the age of five (West et al., 1991).
- In a carefully controlled study in Madurai, South India, small weekly doses of vitamin A that simulated recommended dietary intake



resulted in significantly reduced mortality (Rahmathullah et al., 19[illegible]). The low dose used in this trial confirms that mortality effects can be expected from successful dietary modification programs.

Careful monitoring can help focus resources on those in greatest need.

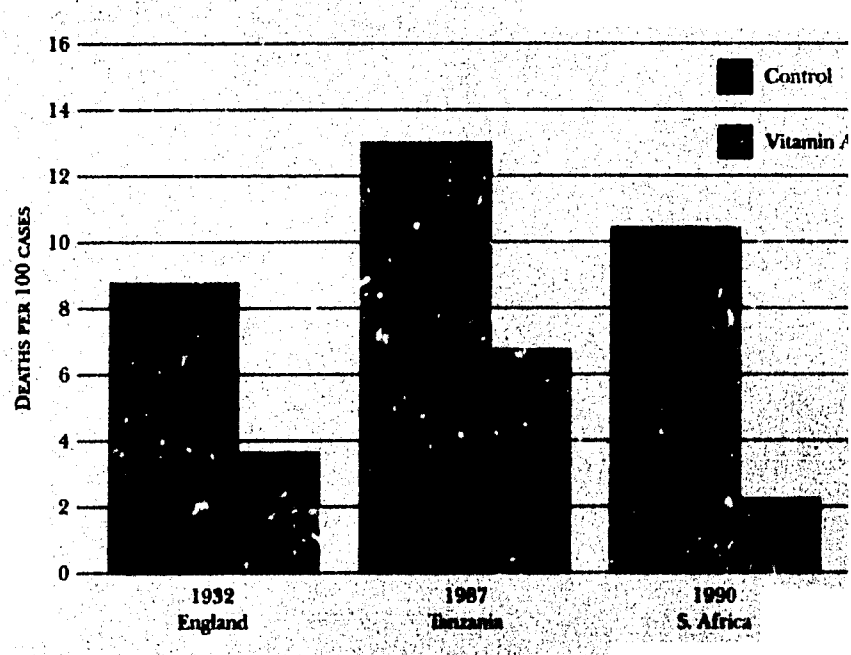
Vitamin A Treatment for Measles Reduced Case Fatality by One-Half. An estimated 880,000 to 1.36 million infants and young children lose their lives to measles each year. Although immunization is an effective preventive measure, to date there has been no specific treatment for the disease. However, with vitamin A treatment, it may be possible to reduce severe measles mortality by one-half and to prevent eye damage — even in areas where vitamin A deficiency is generally not considered a severe problem. Over the past 60 years, studies have been conducted on the treatment of severe measles with vitamin A in countries as diverse as England (Ellison, 1932), Tanzania (Barclay et al., 1987), and South Africa (Hussey and Klein, 1990) *(see Box 2)*. In these trials, children who were treated with large-doses of vitamin A on admission (or given cod liver oil throughout their illness in the older English study) experienced a 50 percent or greater reduction in fatality. In each trial, the clinical severity of measles complications was reduced among survivors.

- In a clinical trial conducted during the measles season in Tanzania, 180 children under six years of age admitted to the hospital for measles were randomized to receive either vitamin A treatment (200,000 IU of vitamin A on the day of admission, and another 200,000 IU dose on the following day) or the standard management of measles without vitamin A. Measles mortality in the supplemented group was 6/88 (7 percent) compared to 12/92 (13 percent) among the controls. The difference was not statistically significant but was greatest for children under two years of age and for children with croup and lung disease (Barclay et al., 1987). None of the children evidenced eye changes associated with vitamin A deficiency before measles.
- A randomized, double-blind, placebo-controlled vitamin A intervention trial was conducted on 189 non-xerophthalmic children with acute measles in Cape Town, South Africa (Hussey and Klein, 1990). The treatment group received two doses of vitamin A (200,000 IU per dose) with a one-day interval. Of the 12 children who died, 10 had received the placebo. Treated children recovered more quickly from pneumonia and diarrhea and evidenced less croup.

Studies in Zaire and in Durban, South Africa, produced similar results. It appears, then, that vitamin A supplements overcome severe reductions in circulating levels of retinol that are consistently observed in measles patients, even in areas where vitamin A deficiency is not otherwise a serious problem. Other studies have shown that low serum retinol levels are associated with mortality, although the mechanism of this action is still not understood. In the Cape Town study cited above, no child with a serum retinol above 20 µg/dl died. Because lowered serum retinol during measles is observed even in communities where vitamin A stores are not deficient, it is assumed that the mobilization of stored vitamin A is affected by measles or that the body's use of retinol accelerates beyond the capacity to maintain blood levels. When diarrhea accompanied measles, it did not reduce the effectiveness of orally administered vitamin A in maintaining circulating levels of retinol.

Box 2

Vitamin A Impact on Measles Mortality



SOURCES: *Ellison, 1932; Barclay et al 1987; Hussey and Klein 1990.*

Severely Iron-Deficient Pregnant Women Are More Susceptible to Death. Women with severe iron-deficiency anemia (hemoglobin levels below 8.0 g/dl) are less tolerant of blood loss at delivery. Thus, when malaria and/or hookworm lowers the oxygen-carrying capacity of red blood cells (RBCs) even further, iron-deficient women are prone to death from the added stress of labor, spontaneous abortion, or other complications (INACG, 1990). Overall, one-fifth of maternal deaths may be attributable to severe iron-deficiency anemia in

pregnancy (Levin et al., 1991). The consequences of maternal iron-deficiency anemia for infants are higher perinatal mortality and low birth weight. Low birth weight is, in turn, associated with high infant mortality rates.

Iodine Deficiency Significantly Increases Stillbirths and Infant Deaths. Iodine-deficient women demonstrate an increased rate of spontaneous abortion and stillbirth, both of which can be reduced by remedying the iodine deficiency. Similar benefits have been demonstrated after pregnant women diagnosed with hypothyroidism were treated with iodine (McMichael et al., 1980). ■ The results of a controlled trial in Zaire of iodized oil injections administered during the latter half of pregnancy showed a substantial fall in perinatal and infant mortality as well as an increase in birth weight (Thilly, 1981) *(see Box 3)*. An increased risk of death throughout childhood was demonstrated among unsupplemented groups in a follow-up of a controlled trial with iodized oil in Papua, New Guinea (Pharaoh et al., 1971). In Asia, this excess mortality is estimated to be 2.6 stillbirths per 1,000 live births and 2.4 neonatal deaths per 1,000 live births (Clugston et al., 1987).

Significant Numbers of Excess Deaths in Refugees and Displaced Populations Are Attributable to Micronutrient Deficiencies. Among the 30 million refugees and displaced persons estimated to have needed assistance in 1990, mortality rates up to 60 times the expected rates have been attributed, in part, to micronutrient deficiencies (Toole and Waldman, 1990). Specifically, vitamin C

Box 3

Impact of Iodized Oil (Zaire)

	Not treated	Treated
Birth weight (g)	2654± 558 (98)	2857± 542* (112)
Perinatal mortality per 1000	168 (125)	98* (129)
Infant mortality per 1000	250 (265)	167* (252)
Developmental quotient	104±24 (66)	115±16* (72)

*Significant difference

Source: Hetzel, 1989 from Thilly, 1981

and other preventable micronutrient deficiencies, which were thought to have been eliminated decades ago, were implicated in the excessively high mortality rates.

Micronutrients Prevent Mental and Physical Disabilities

Iodine Deficiency Lowers Mental Performance. Iodine deficiency is the major preventable cause of mental retardation worldwide. The I.Q. levels of children born to iodine-deficient mothers were about 15 percent lower than those of non-deficient groups in studies conducted in Ecuador and Zaire (Hetzel et al., 1987). In addition to its well-documented effects on mental development, iodine deficiency is often a factor in hearing loss.

Vitamin A Deficiency Is the Largest Cause of Childhood Blindness in Developing Countries. Because their diets lack sufficient vitamin A to meet their needs, 1 million preschool-age children worldwide develop severe eye disease each year. Of this number, 60 percent die, and, of the survivors, 25 percent remain totally blind, and 50 percent to 60 percent are partially blinded for the remainder of their life (Underwood, 1990).

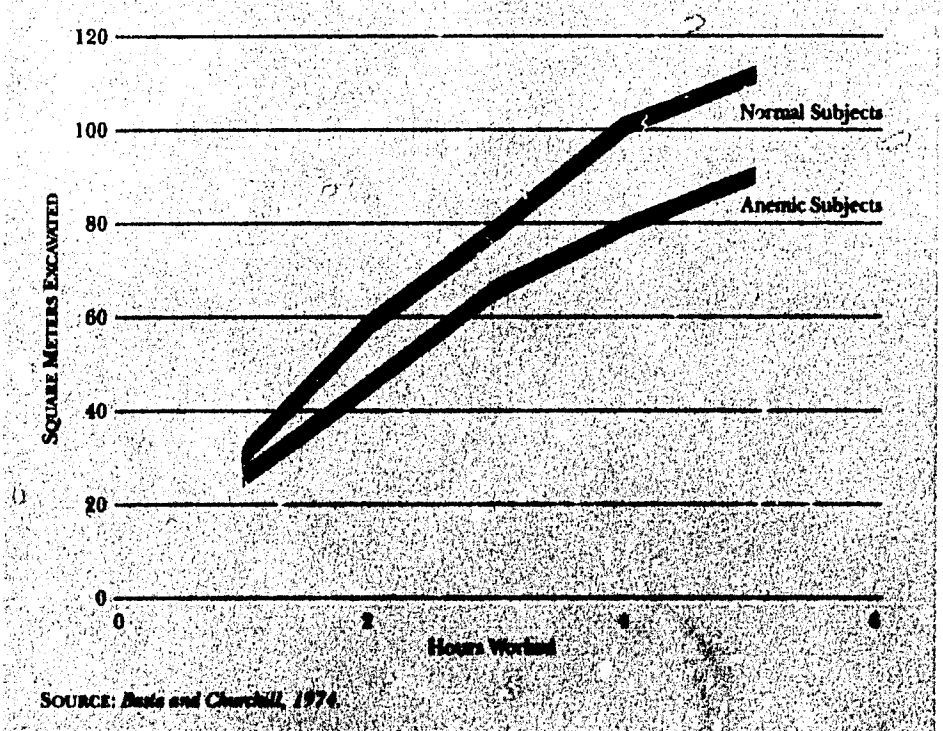
Iron Supplementation of Iron-Deficient Children Can Lead to Dramatic Improvements in Mental and Motor Skills. Studies in India, Thailand, and Indonesia showed that iron supplements improved the achievement test scores of school children by 5 percent to 25 percent (Levin et al., 1990). Children in Chile who had undergone iron repletion performed significantly better on tests of mental and motor skills. Because of iron deficiency's long-lasting effects on mental development, the available evidence strongly suggests the need for preventing iron deficiency in infancy and before birth.

Everyone involved in saving and improving the lives of mothers and children – from policy makers to consumer groups, industry, academicians, community volunteers and health workers – can make a difference.

■ Preschool children in Costa Rica who experienced iron-deficiency during infancy were tested using standardized tests of mental and motor performance. Moderate iron deficiency was found to be associated consistently and significantly with lower scores in a large number of the tests. These differences persisted even though the signs of iron deficiency had disappeared as the children grew older (Lozoff et al., 1991).

Box 4

Effect of Iron-Deficiency Anemia on Daily Work Output



Source: *Basta and Churchill, 1974.*

Micronutrients Improve Worker Productivity

Iron Deficiency Decreases Work Output. Latex workers in Indonesia (Basta and Churchill, 1974) and tea plantation workers in Sri Lanka (Edgerton et al., 1972) demonstrated reduced physical capacity and output when their iron status was low. Studies indicate that, with each 10 percent increase in hemoglobin, a 15 percent improvement in the productivity of anemic laborers can be expected (Levin, 1985) *(see Box 4).*

Vitamin A and Iodine Deficiencies Contribute to Lost Productivity. Visual impairment is related to vitamin A deficiency. Apathy and lethargy associated with iodine deficiency are other sources of lost productivity. Iodine deficiency, in turn, is associated with hypothyroidism. Studies have shown dramatic changes in productivity as a result of iodine supplementation.

Micronutrient Deficiencies Affect Large Segments of the Population

In many countries, one-half or more of the total population is affected. Estimates put the worldwide total at approximately 1.5 billion people *(see Box 5).* Further, the past few years have seen a resurgence of

deficiencies once thought to have been eliminated among refugees and displaced persons. Currently, vitamin A, iron, and iodine deficiencies pose the greatest concern, but zinc, vitamin C, the B vitamin group, and calcium deficiencies may prove to be important as well.

Micronutrient Programs Are a Sound Economic Investment

The economic value of addressing micronutrient deficiencies far surpasses the cost of interventions, some of which are estimated at only a few cents per person per year. The reduced burden of illness, death, and poor mental and physical capacity that can be brought about by remedying micronutrient deficiencies represents a savings to families, to communities, and to agriculture, education, industry and other sectors that rely on human resources. Based on a conservative analysis of the economic returns from iron fortification, Levin (in a World Bank study that used data from Kenya, Indonesia, and Mexico) concluded that, even taking into account assumptions about replacement of labor and increased energy requirements for the increased work, iron fortification is highly cost-effective. Dramatic changes in income and economic development have been reported from iodine-deficient areas in China following salt iodization in 1978 (Hetzel, 1989). Based on estimates of the cost of each discounted healthy life year gained for over 20 interventions, vitamin A activities ranked throughout the world among the most cost-effective health and nutrition interventions for child survival (McGuire, 1990).

Box 5

Magnitude of the Problem

■ Iron deficiency	1.3 billion people 24% of world population[1]
■ Iodine deficiency	217 million people 4% of world population[2]
■ Vitamin A deficiency	43 million children under 5 7% of the world's children under 5[2]

SOURCES: *1. ACC/SCN, 1991. 2. Adapted from The Hunger Report: Update 1991*

Ensuring Access to Micronutrients

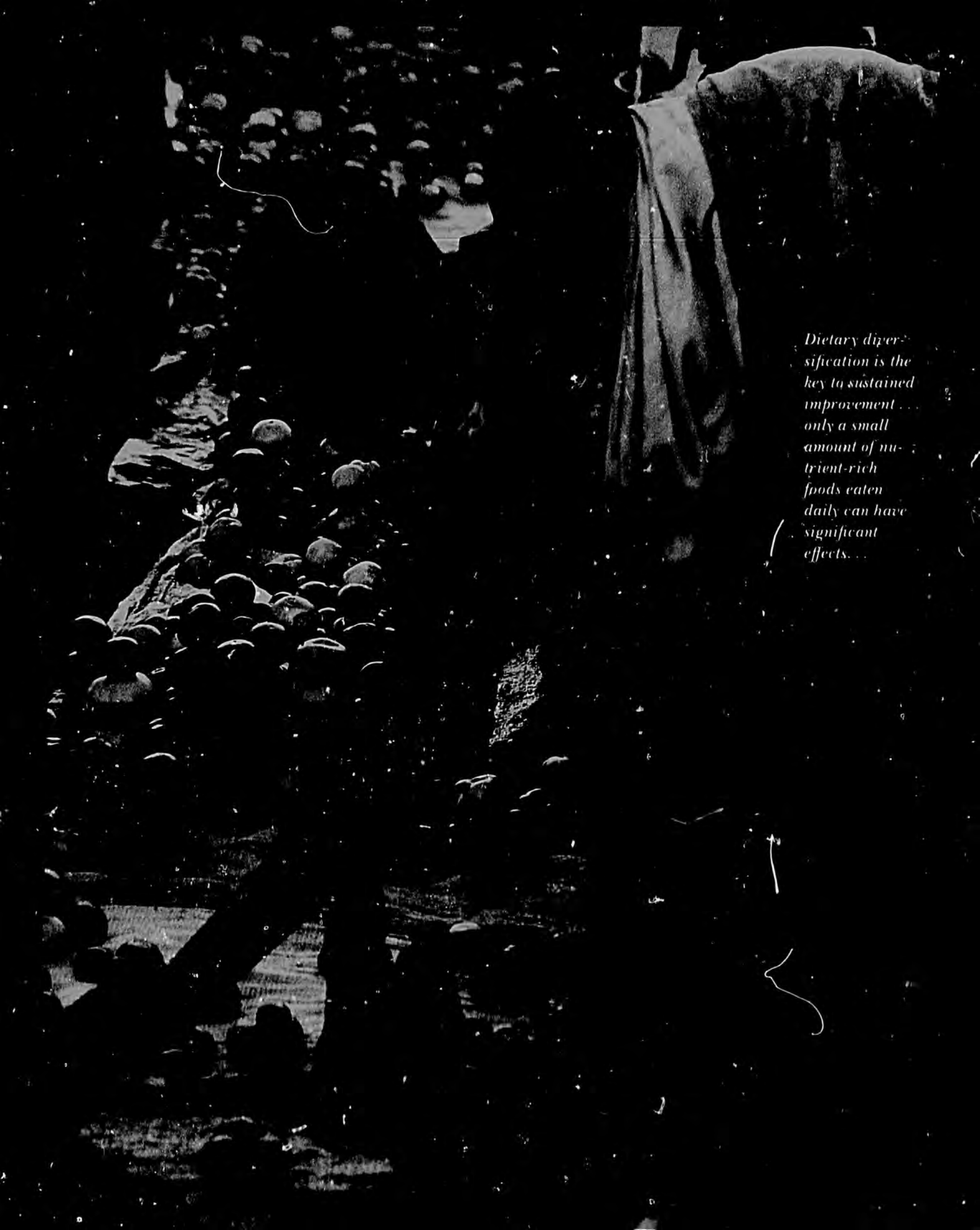
World leaders and scientists agree that the need for action is great to ensure that the world's population has adequate access to needed micronutrients. They also agree that the technical capabilities required for action are commensurate with the challenge.

Global targets for the 1990s have been established *(see Box 6)*. Now the arena for action is shifting to individual nations that assume responsibility for making decisions on appropriate interventions to combat micronutrient deficiencies.

Options for national strategies may be based on past experiences in successfully controlling micronutrient deficiencies with known technologies that point to a mix of different interventions. Interventions available for improving micronutrient status include dietary diversification through expanded education and home food production, supplement distribution programs, and food fortification. *Box 7* presents the three main classes of interventions. In the final analysis, each nation will need to concentrate its resources on the most practical and cost-effective ways of overcoming specific, local constraints to improving micronutrient consumption. The elements of a comprehensive program are described in the remainder of this section.

Understanding Who Is at Risk and Why

Action at the national level must begin with a better understanding of the nature and magnitude of micronutrient deficiency problems and their underlying causes. Indeed, some groups are at greater risk than others. *Box 8* lists the factors that determine risk. Careful assessment of micronutrient malnutrition and associated conditions can help focus resources on those in need. For example, vitamin A is especially important after weaning and during the childhood years because of young children's rapid rate of growth and the multiple infections that affect this



Dietary diversification is the key to sustained improvement . . . only a small amount of nutrient-rich foods eaten daily can have significant effects. . .

group. Iron deficiency is prevalent during infancy, early childhood, adolescence, and the reproductive years of women (especially during pregnancy) because of rapid physical growth and blood loss during menstruation and delivery. Iodine nutriture should be adequate especially during pregnancy and in the first months of life when the neurological development of the fetus and newborn is taking place.

Box 6
Global Targets for the 1990s
(World Summit for Children, September 1990)

- **Virtual elimination of vitamin A deficiency and its consequences, including blindness**
- **Reduction of iron-deficiency anemia among women of child-bearing age to one-third of 1990 levels**
- **Virtual elimination of iodine-deficiency disorders**

NOTE: ***Because these deficiencies are likely to co-exist in the same population, they may be controllable within a common strategy.***

Box 7
Interventions

- **Dietary diversification: nutrition education, food production, and preservation**
- **Micronutrient supplementation**
- **Food fortification**

A range of field assessment methods can identify high-prevalence areas within countries where recent micronutrient assessments have not been conducted. *Box 9* lists the major categories of assessment methods. Country strategies will need to be based on realistic estimates of the magnitude of the deficiencies and on finding the best way of reaching communities at greatest risk.

Dietary Diversification, Nutrition Education, and Local Food Sources

Dietary modification to increase consumption of micronutrient-rich foods is considered the safest and most sustainable, long-term measure to control most micronutrient deficiencies. In many communities, micronutrient-rich foods are underused in the diets of vulnerable groups, particularly weaning-age children and pregnant and nursing women. Traditional customs and beliefs occasionally limit use of micronutrient-rich foods for these groups even where such foods are readily available.

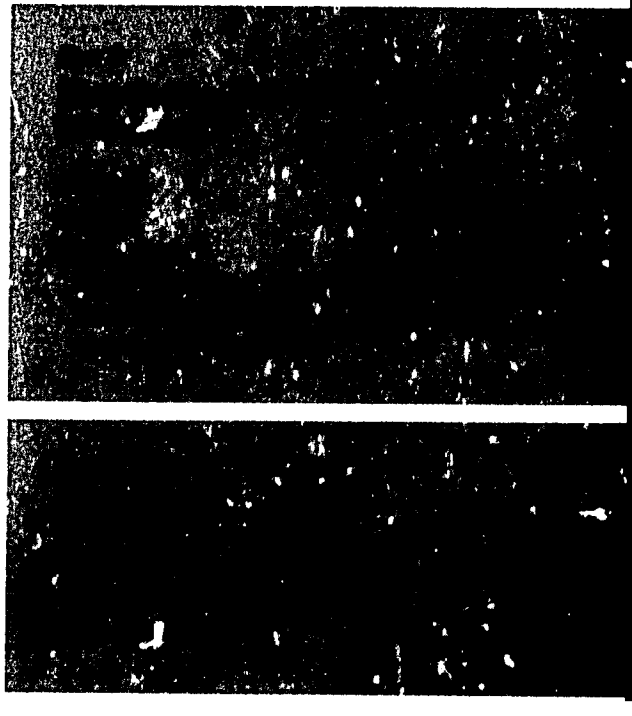
■ Villagers in northeast Thailand have long consumed the fruit of the ivy gourd plant but only recently have they started to eat the plant's leaves — a rich source of β-carotene. Mahidol University, with assistance from A.I.D., mobilized villagers to relay information on the benefits of the ivy gourd and on the importance of children's nutritional health. Community organizations successfully devised simple

methods for cultivating the ivy gourd at lower elevations so that villagers could easily collect the plant's leaves. Recipes were developed and field tested for acceptability. Private advertising firms campaigned through the mass media and through in-person contacts to improve the image of the ivy gourd's fruit *and* leaves and to promote the importance of vitamin A for children.

■ In Mali, CARE, World Vision, Africare, and Save the Children are carefully assessing attitudes, practices, and conditions under which rural mothers have to work and feed their children. These same organizations are also considering options for increasing vitamin A intake and for enhancing nutritional status through the consumption of locally available foods.

■ In Indonesia, daily fruit consumption (mango and papaya) was associated with the absence of vitamin A deficiency in toddlers. At older ages, dark green leafy vegetables are an important source of β-carotene for children.

■ Only small amounts of foods rich in micronutrients are needed to meet daily requirements. Studies in India have shown that the consumption of 30 grams of dark green leafy vegetables per day for three months prevented low serum retinol levels for four to five months (Sommer, 1982). In the recent mortality reduction study in Madurai, South India, the level and dosing schedule of supplement use was based on a simulation of daily dietary intake of recommended levels of vitamin A. Instead of massive dosing at infrequent intervals, a low dose was given weekly and obtained a higher mortality-suppression effect than did high dose supplements. *Box 10* shows the amounts of food needed to fulfill vitamin A needs.



Because a major dietary factor in iron nutrition is the presence of iron inhibitors in cereal-based diets, a cost-effective way of improving iron status among low-income families is to encourage consumption of vitamin C-containing foods. Vitamin C

increases absorption of dietary iron *(see Box 11* on the effects of vitamin C on vegetarian diets). Fruits and vegetables are a good source of vitamin C; in fact, some provide both vitamin C and β-carotene.

Box 10
Daily Vitamin A Requirements
(amounts are approximate)

Age Group	Food Sources (examples)			
	Breastfeeding	Carrots	or DGLV*	or Mango
Children				
■ 0-5 months	Exclusive Breastfeeding			
■ 6-11 months	Breastfeeding +	⅓	¼ cup	¼
■ 12-35 months		½	⅓ cup	⅓
■ 4-6 years		¾	½ cup	½
Pregnant Women		2	1 cup	1
Lactating Women		3	1½ cup	1½

**DGLV = Dark green leafy vegetables*

SOURCES: *1. Vitamin A + Sieve, 1986: compilation of various food composition tables.*
2. The Composition of Foods Commonly Eaten in East Africa, 1988

■ In the Basta et al. (1974) Indonesia study, the equivalent of 3 U.S. cents per day spent mainly on green leaves provided sufficient available iron (3-5 mg) in addition to small amounts of protein, vitamin A and vitamin C. This was sufficient to correct anemia, despite the continued presence of hookworm in the study population.

■ Further, even small amounts of meat or fish can appreciably enhance iron absorption from the total diet. Abstaining from tea drinking with meals also promotes the absorption of dietary iron as tannins in tea are strong inhibitors to iron absorption. *Box 12* shows commonly available foods grouped by micronutrient content.

Household gardens play a critical role in many communities. They guarantee a regular and secure supply of food, petty cash, or goods to trade. A number of food items are produced at home by women and other family members who may be unable to work outside the home. The gardens ensure a supply of food during periods of crop failure or disruption in food supplies. Data collected in Africa suggest that the major supplier of many micronutrients, particularly vitamin A, is the household or community garden. Most populations at risk of developing vitamin A deficiency appear to receive most, if not all, of their vitamin A from carotene-containing fruits and vegetables, many of which can be grown in home and community gardens. Such foods tend to be seasonal, but because vitamin A is stored in the body, intake at levels many times the normal daily requirement can ensure adequate liver stores to cover those

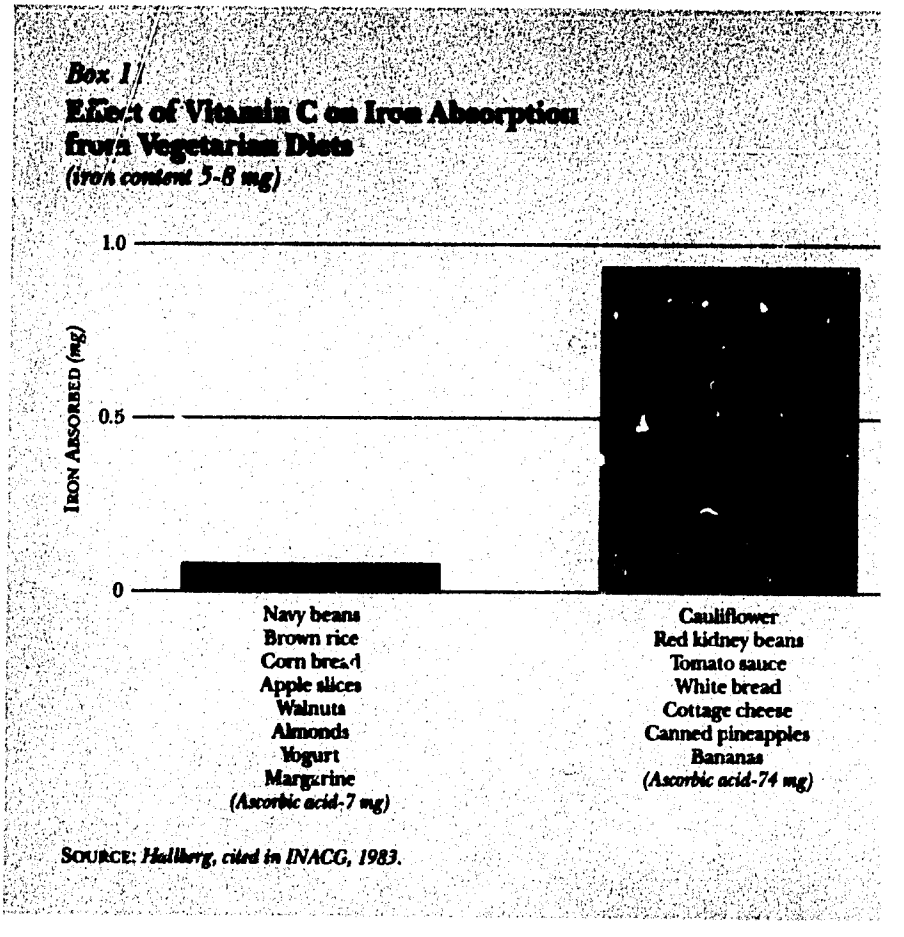
periods when availability and consumption are low. The role of vitamin C-rich fruits and vegetables in increasing iron absorption is well documented.

Simple technologies can play a major role in ensuring the success of home gardens and thereby the consumption of needed micronutrients.

■ Though rich in water and sunshine, the cold and windswept Bolivian Altiplano has had limited success with home gardens. To overcome the harsh conditions, two voluntary organizations, Food for the Hungry and Freedom From Hunger, introduced greenhouses in the region The 16-meter-square adobe structures, topped with sun-resistant plastic roofs, helped increase supplies of carrots, lettuce, cucumbers, radishes, and tomatoes.

■ In Nepal, remote hill communities cut off from regular food supplies for substantial periods of the year have found that home and community gardens are a critical source of food. CARE helped devise simple wind shields that also act as greenhouses and thus extend the growing season by many months. Now nutrition education messages are being planned to accompany the gardening activities so that more vitamin A-rich foods are fed to young children and women.

Food preservation techniques can help bridge the seasonal gaps in availability. A.I.D.'s Vitamin A Field Support Project



(VITAL) has found that solar drying is an appropriate technology for the preservation of such vitamin A-rich foods as mango, papaya, sweet potato, pumpkin, and green

Gardens play a critical role in many communities, guaranteeing a regular and secure supply of food, petty cash, or goods to trade. . . Food preservation can help bridge the seasonal gaps in availability.

leaves. Solar drying can be adapted and transferred to a variety of locations with a relatively small amount of technical assistance.

In many areas, foods such as mangos are especially plentiful during a short growing season but, because they ripen quickly, large quantities of the fruit are lost due to lack of transport opportunities and limited knowledge of preservation techniques. By using an inexpensive and available energy source, solar drying can minimize post-harvest loss, enhance the value of crops for producers, and increase household food security and the availability of vitamin A-rich foods during the off-season. Properly solar-dried mangos retain a markedly high level of β-carotene and can be stored for as long as four to six months without losing their nutrient value. Dried produce can be easily transported to other regions of the country, allowing producers to sell their products to a larger consumer base and to take advantage of favorable market conditions.

■ Save the Children in Haiti is encouraging solar drying by women's groups *(Gwoup Famn Decidé)* to preserve mangos and other vitamin A-rich foods grown in the central plateau region. A.I.D. is providing technical assistance in dryer construction, solar-drying techniques, recipe development, nutrition education, and marketing of the dried produce. A revolving credit fund has been established to finance individual

Box 12

Examples of Micronutrient-Rich Foods

High Concentration of VITAMIN A	High Concentration of VITAMIN C	High Bioavailability of IRON
Amaranth leaves	Amaranth leaves	Alfalfa shoots
Baobab leaves	Bean sprouts	Amaranth leaves
Basil leaves	Beet greens	Beef
Beef liver	Broccoli	Blood
Carrot	Cabbage	Chicken
Cassava leaves	Citrus fruit	Fish
Chicken liver	Citrus fruit juice	Organ Meat
Cow pea leaves	Green pepper	Pork
Goat liver	Guava	Shell fish
Kale	Mango, ripe	Spinach
Mango, ripe	Papaya	
Red palm oil	Pineapple	
Red pepper	Red pepper	
Red pimiento	Spinach	
Red sorrel		
Spinach		
Yellow, orange sweet potatoes		

■ Absorption of β-carotene (a precursor of vitamin A) from plant sources requires a small amount of fat.

■ Food preservation methods and cooking methods can reduce vitamin A and vitamin C activity if vitamin-rich foods are subjected to high temperature and sunlight. Boiling is preferable to frying, and air-drying food protected from direct sunlight is better than air-drying food directly exposed to sunlight. Cooking a whole food item then mashing or cutting it is preferable to cutting before cooking. Vitamin C levels are highest when products are consumed raw shortly after harvesting.

■ Often the least costly and most available green leafy vegetables may be bland, slightly bitter, or too fibrous and therefore considered inappropriate for infant and young-child feeding. However, boiling, mashing, straining, and mixing the green leafy vegetables with other well-liked foods can make them palatable and digestible.

ventures. Once the women become proficient in the technology, they will become trainers for women's groups in neighboring villages. In recognizing the importance of income generation for sustainability of the activity, the project includes training in financial management and record-keeping as well as in solar-drying technology. *The Centre de Developpement des Ressources Humaines* (CDRH) in Haiti has drafted both a Creole- and English-language manual on solar-drying techniques. The manuals discuss dryer construction, food preparation, and storage and marketing guidelines for project development.

No matter how geographically remote a community, most families have some access to vitamin- and mineral-rich foods. Many wild plants and commonly available dark green leafy vegetables, as well as animal sources such as organ meats, eggs, and whole milk are excellent sources of micronutrients. In some communities, fish cultures and home production of animal products is important in improving access to micronutrients and in ensuring their consumption. Horticulture and gardening programs and solar drying and other food preservation methods can alleviate seasonal variation in food availability. Through nutrition education, families can be taught to use local food sources and to improve their overall nutritional status in a permanent way.

Micronutrient Supplements

Dietary intake is the key to sustained improvement in micronutrient nutrition. However, where local and fortified foods are not an option, supplements are an excellent alternative. Vitamin A, iron, and iodine are readily available in concentrated or synthetic forms at low cost. Therefore, it is possible to distribute these micronutrients as capsules, tablets, or injectable solutions. WHO/UNICEF and the specialized consultative groups—International Vitamin A Consultative Group (IVACG), International Nutritional Anemia Consultative Group (INACG), and

International Center to Control Iodine Deficiency Disorders (ICCIDD)—have developed dosage schedules and supplementation protocols for various age and risk groups. Operational constraints in expanding coverage with supplements include an overdependence on, and lack of support for, weak segments of public sector-run health services responsible for the diagnosis, treatment, prevention, and monitoring of vitamin and mineral deficiencies.

A major advantage of supplementation is that highly concentrated doses of micronutrients can be administered for treatment of severe deficiencies—with immediate impact and reduction of mortality risk. Vitamin A supplements can be given frequently (weekly or monthly) at doses that are consistent with recommended dietary allowances or in high concentrations at four- to six-month intervals. Because the vitamin is stored in the liver after absorption, it continues to be released into the bloodstream as needed, providing protection for several weeks or months. The most widely used form of high-dose vitamin A supplementation is a soft gelatin capsule that contains 200,000 IU of vitamin A. UNICEF is the primary supplier of capsules. Supplements also take the form of liquid concentrates that can be dispensed from precalibrated, reusable spray bottles. Iron supplements are most commonly available as tablets to be taken daily. Iodized oil can be administered through injections or orally, with protection provided for three to five years (injected) or about two years (oral).

Vitamin A supplements cost approximately two U.S. cents per dose. The existence of an appropriate delivery system, especially when no additional transportation or personnel costs are required, can reduce the total cost considerably. For example, in Bangladesh, Mills (1983) estimated the cost per person

year of protection to be five U.S. cents. The cost per person year of protection from vitamin A capsule distribution programs in Indonesia and the Philippines was estimated to be about 50 U.S. cents (Levin et al., 1990). The cost per person year of protection from iodized oil is estimated to be 14 to 46 U.S. cents. Based on estimates from Indonesia, Mexico, and Kenya, Levin (1985) estimated the cost of iron tablet distribution programs to be in the range of U.S. $2.50 to U.S. $4.50 per person year of protection. *(see Box 13).*

Box 13

Costs of Interventions

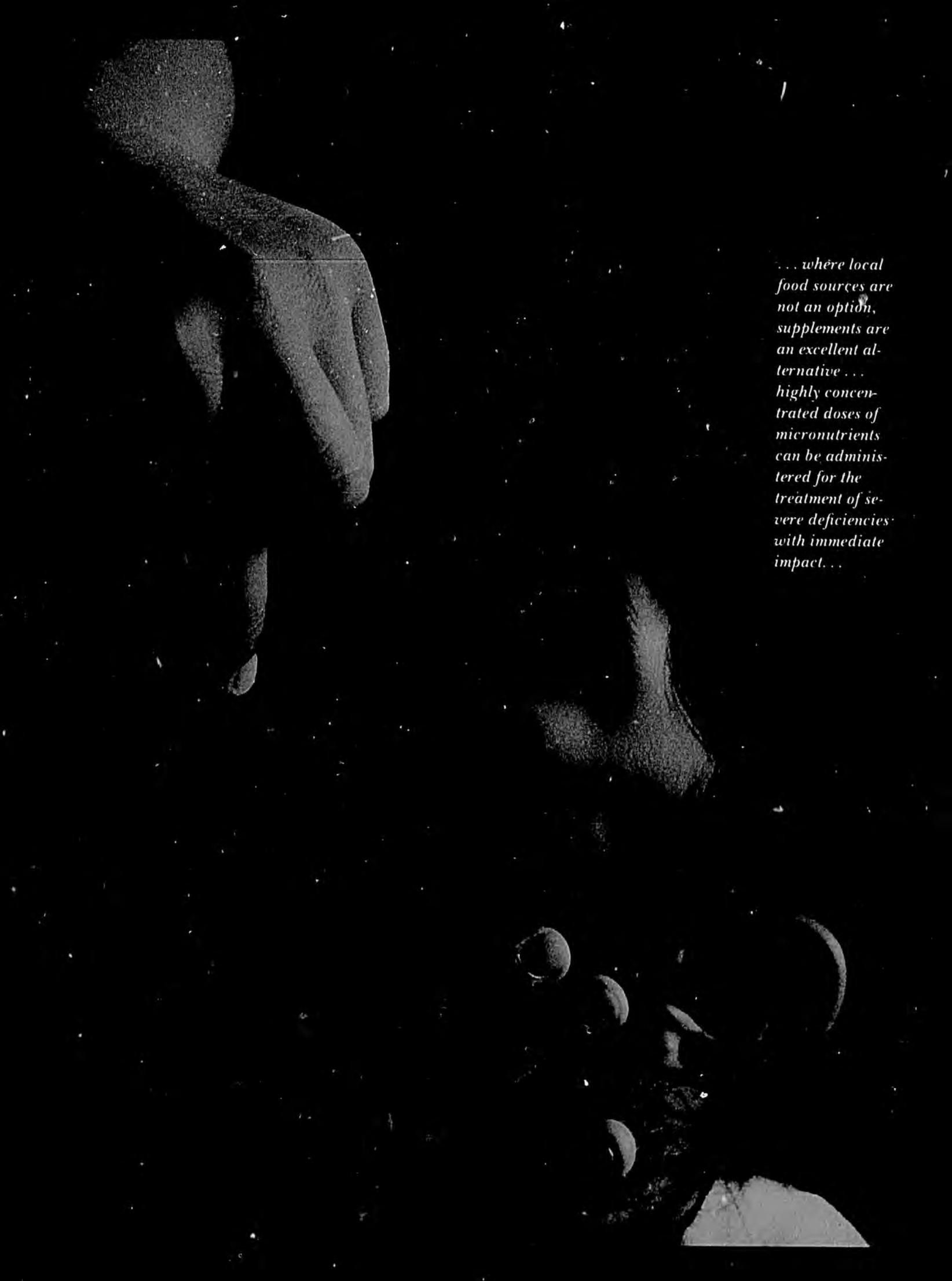
Intervention	Country/Year	Estimated Cost Per Person Per Year of Protection (US $)
Iodine		
Oil inj.	Peru 1978	.46
Oil Inj.	Zaire 1977	.14
Water fort.	Italy 1986	.04
Salt fort.	India 1987	.04
Vitamin A		
Sugar fort.	Guatemala 1976	.14
Capsule	Haiti 1978	.46–.68
Capsule	Asia 1975	.42
Capsule	Bangladesh 1983	.05
Iron		
Sugar fort.	Guatemala 1980	.10
Sugar fort.	— 1980	.84
Tablets	— 1980	2.65–4.44

SOURCE: *Levin et al. 1990*

A priority intervention for the control of iron-deficiency anemia is supplement distribution to all women of reproductive age in developing countries. Supplements should not be limited to pregnant women. Many women enter pregnancy with a pre-existing iron deficiency. Recent breakthroughs in the technology of iron supplements have shown that it is possible to improve absorption and reduce side-effects — problems that previously limited women's receptivity to iron supplements. Ferrous sulphate in the new supplement is retained in the stomach for five to 12 hours and is gradually released, thereby protecting iron against poor absorption by the common iron inhibitors found in cereal-based foods.

Iodized oil is most commonly administered by intramuscular injection. Absorption into the blood occurs slowly, and a single dose provides protection for several years. This intervention is particularly suitable for remote or isolated communities. Mobile teams in Papua, New Guinea, and in Zaire and community health workers in China and Indonesia administered the injections.

The effectiveness and cost of a supplement distribution program depend to



. . . where local food sources are not an option, supplements are an excellent alternative . . . highly concentrated doses of micronutrients can be administered for the treatment of severe deficiencies with immediate impact. . .

a large extent on the delivery system used. Integrating a distribution program into already existing community outreach programs such as Maternal and Child Health (MCH), agricultural extension, primary schools, and immunization programs is more feasible than setting up single-purpose micronutrient distribution channels. Many countries distribute vitamin A and iodine through ongoing immunization programs.

Food Fortification

Micronutrient-fortified foods can be integrated into the conventional food system as value-added products that reach a large segment of the population. They require no changes in food beliefs and practices. Through judicious selection, fortified foods can be targeted to specific population groups or the general population. Fortification is not a simple undertaking, however. Current constraints include underdeveloped food processing and pharmaceutical production and supply capability as well as the lack of regulatory, enforcement, and oversight capacity for food additives and food and drug quality. Food fortification efforts must first identify a suitable food for fortification; that is, the food must consistently reach the target group(s). Nutrients added to the food must not change a food's appearance or taste and must be bioavailable and not inhibited by other components of the diet.

Iron-deficiency anemia and iodine deficiency appear particularly amenable to remediation through fortification. In fact, food fortification with iron and iodine has been underway in developed and developing countries for decades. Developed countries have been fortifying butter and margarine with vitamin A for many years. By contrast, developing

countries are less experienced in vitamin A fortification programs, although Guatemala and Costa Rica (and more recently El Salvador) have successfully fortified sugar with vitamin A.

Experience in developed countries suggests that fortification programs should be designed to be self-sustaining. Consumers should recognize the benefits of fortification at costs that permit a reasonable profit for the supplying industry. Mandatory micronutrient fortification of specific foods within the context of a broader micronutrient-deficiency control strategy can be extremely effective in a number of countries that command the means to monitor and enforce compliance. It is believed that iron fortification of bread, bakery products, infant cereals and infant formulas has virtually eliminated the problem of iron deficiency in the U.S. and other developed countries, except perhaps among pregnant women.

■ Studies conducted since the 1970s on fortifying a broad range of foods and condiments with iron showed improvements in iron status (as measured by packed cell volume, iron stores, hemoglobin, and serum ferritin), particularly in iron-deficient groups (Lynch, 1990). In developing-country diets, however, the presence of phytates and other factors in cereal bran greatly reduces the effectiveness of any iron fortificant except iron EDTA, a fortificant that remains absorbable (Hurrel, 1990). Iron EDTA has been highly effective in fortification trials with Egyptian flat breads, curry powder in South Africa and sugar in Guatemala. Vitamin C increases iron availability, but fortification with vitamin C has not yet been found to be cost-effective.

■ In Indonesia, iron-deficiency anemia affects 20 percent to 60 percent of the population, especially pregnant women and preschool-age and school-age children. Recent knowledge of the effects of iron deficiency on mental function (in addition to iron deficiency's well-known effects on physical capacity) has led to a new national policy to expand anemia reduction efforts beyond supplement distribution. Based on

studies of food patterns, salt and noodles have been selected as vehicles for iron. The cost and feasibility of monitoring and enforcing a nationally mandated system for the double fortification of salt with iron and iodine and the single fortification of noodles with iron are currently major concerns (Karyadi, 1990).

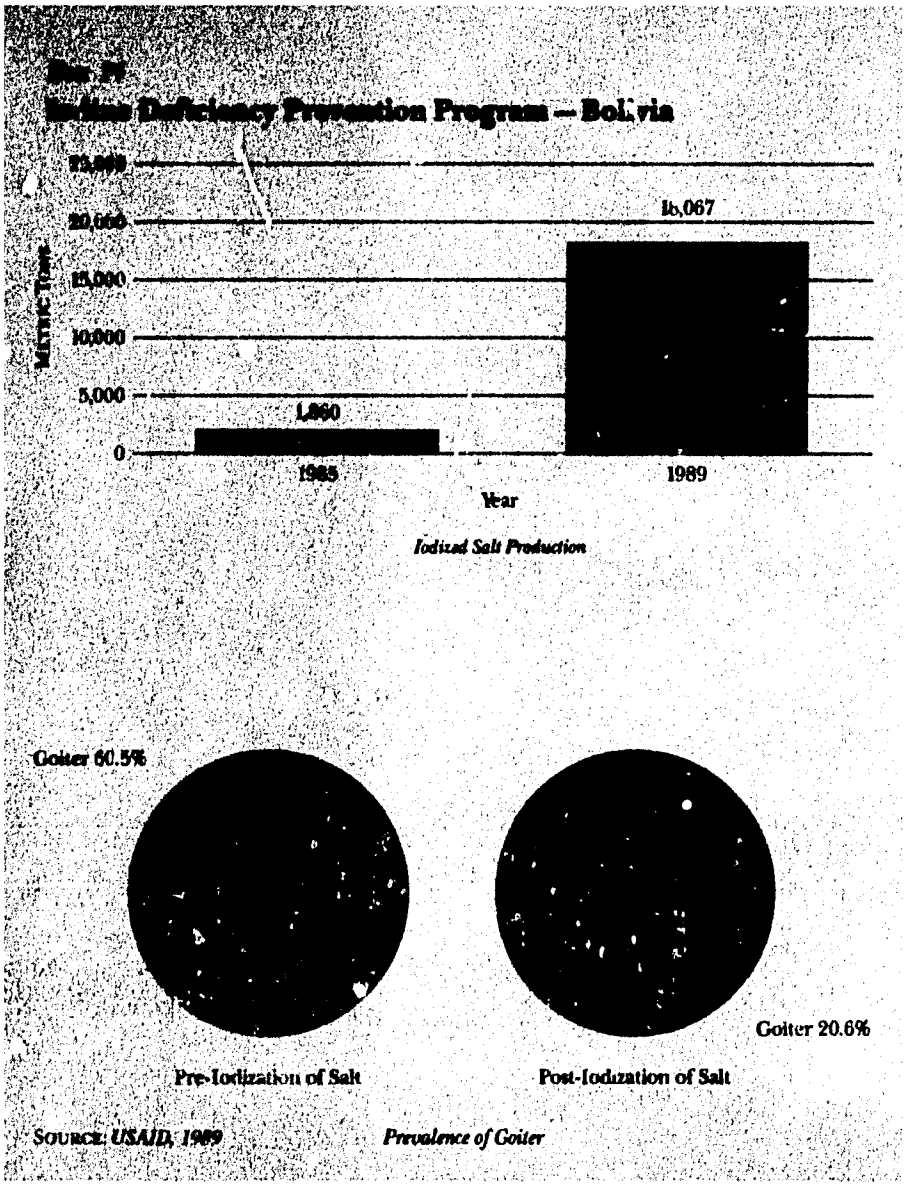
- In Ecuador, three foods are being evaluated for iron fortification, namely, wheat flour, salt, and sugar. These food products are widely consumed by all social classes. Because they are processed at relatively few locations, monitoring for quality control is relatively easy. Salt is currently used for iodine fortification (Freire, 1990).

Food fortification, where practical, is one of the most cost-effective interventions over the near term for improving micronutrient status. The estimated cost of iron fortification of sugar in Guatemala and of iron fortification of salt in India (Cook and Reusser, 1983) per person year of protection was estimated to be 10 U.S. cents. Using different assumptions, Levin (1985) estimated sugar fortification with iron to cost 84 U.S. cents per person year of protection. Salt iodization costs an estimated two to six U.S. cents per year per person. Cost estimates of prevention programs (McGuire, 1990) suggest that the cost of supplement distribution for iron, vitamin A, and iodine are on the order of four to 10 times higher (per person year of protection) than food fortification with these micronutrients. By comparison, dietary improvement offers the potential for self-sustaining benefits (zero long-term program costs) after an initial investment has been made in nutrition education/communications and food production/preservation activities.

Iodization of drinking water has been effective in Thailand. The technology for salt iodization is simple. But successful implementation of such a program may take several years, especially if changes in the salt trade are involved. Nevertheless, dramatic

. . . dramatic reductions in goiter prevalence have been documented in several countries following salt iodization. . . . iron fortification of bread, cereals, and infant foods has virtually eliminated iron deficiency in developed countries, except among pregnant women.

reductions in goiter prevalence have been documented in several developed and developing countries following salt iodization.



■ The government of Bolivia initiated a national program of iodine deficiency control in 1984. The government distributed Lugol's iodine (6 mg iodine per drop) to pregnant women, undertook national campaigns to administer oral and injectable iodized oil, and distributed iodized salt through health posts. Subsequent activities involved the revision of existing legislation and technical norms, installation of iodization systems at salt processing sites, sensitization of producers regarding the need for iodization, creation of an epidemiological baseline, and the development of appropriate materials for public education. The number of salt production plants increased from two in 1985 to 33 in 1989, of which 28 are private and five are cooperative enterprises (USAID, 1990). *Box 14* shows the results of the Bolivian program.

Designing a Comprehensive Program

Fortunately, problems of micronutrient deficiencies are not insurmountable. The broad outlines of an effective response are known, namely, ensuring that food supplies contain sufficient micronutrients; promoting consumption of micronutrient sources, especially by infants, young children, and women of reproductive age; and reducing the body's overall requirements for various micronutrients

through efforts to reduce the prevalence and severity of contributory conditions such as diarrhea, measles, parasitic infestations, respiratory tract infections, and protein-energy malnutrition.

There is however, no standard package of measures that can transform goals into results, although the key strategies are clear. They include improving access to micronutrient-rich foods in the food supply through fortification and appropriate agricultural and food policies, and motivating communities to adopt dietary practices that include sufficient intake of micronutrient-rich foods, many of which may be readily available. But these measures take time and perseverance, and until they are in place, more immediate measures can fill the gap.

Interventions such as the distribution of supplements provide fast and proven impact but they are not easily sustained; they can be phased out as the more permanent solutions take effect. Nonetheless, supplements will always be an essential component of national strategies for the effective treatment of diagnosed cases of deficiencies. Where increasing consumption of local food sources is not immediately feasible, food fortification offers a low-cost option for delivering micronutrients, especially where large numbers of people are involved. While putting into place the many prerequisites (legislation, technology, monitoring mechanisms, etc.) needed for an effective fortification program, it may be necessary to begin with distribution of preventive doses of supplements in areas and groups that evidence a high prevalence of micronutrient deficiency.

The relative emphasis in any mix of interventions will vary from country to country but should, to the extent feasible, complement work already underway. A systematic appraisal of the country's nutritional situation, relevant policy environment, and resources should form the basis for designing a strategy that fits a country's needs. Applied research to solve operational problems, ongoing assessments, and surveillance activities to track progress and make adjustments in the initial micronutrient strategy are integral elements of a sustainable program. These are the tools which will sharpen the program planner's vision and execution of a comprehensive program to eliminate micronutrient malnutrition.

Conclusion

New research has shown that substantial mortality, morbidity, and physical and mental impairment are attributed to deficiencies of nutrients that are required in small quantities (hence the name *micro*nutrients). Micronutrient deficiencies have important implications for child survival, women's health, educational attainment, labor productivity, and employment.

Large segments of developing-country populations are afflicted with micronutrient deficiencies. In many countries, one-half or more of the total population is affected. Global estimates put the total burden at approximately 1.5 billion people. In fact, the past few years have seen a resurgence in refugee and displaced populations for example, of deficiencies once thought to have been eliminated. With the highly cost-effective technologies now available to remedy these deficiencies, there is no justification for the suffering, disability, death, and economic loss to families, communities, and countries due to micronutrient deficiencies.

Experience with interventions over the past few years suggests that significant reductions in micronutrient deficiency are possible in the near term. Most micronutrients occur widely in nature, and often inexpensive foods can provide a sufficient level of nutrients to meet daily needs. But knowledge of what foods to eat and their importance is often lacking among the affected population. Nutrition education is key.

An important advantage of dealing with micronutrients is the availability of relatively low-cost nutrient concentrates that can be dispensed as supplements or added to a number of processed foods. A range of program options exist for varying country conditions. Everyone involved in saving and improving the lives of mothers and children — from policy makers to consumer groups, industry, academicians, and voluntary health workers — can make a difference.

International agencies including A.I.D. have made the commitment to support these efforts.

Through localized food production and nutrition education families can learn to improve nutritional status permanently and with their own resources.

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History of A.I.D. Support to Prevent and Control Micronutrient Deficiencies

1965—A.I.D. starts vitamin and mineral fortification of nonfat dry milk and blended foods for U.S. donations program.

1969—A.I.D. expands vitamin and mineral fortification to wheat, flour, and cornmeal in U.S. donations program.

1973—A.I.D. commissions review of vitamin A deficiency problems worldwide.

1974—U.S. government proposes global attack on nutritional blindness at the World Food Conference, pledges support, and designates A.I.D. as implementing agency.

1975—A.I.D./WHO cosponsor international meeting in Jakarta, Indonesia, to mobilize global attack on nutritional blindness.

1975—A.I.D. funds International Vitamin A Consultative Group (IVACG) to coordinate activities and facilitate information exchange.

1977—A.I.D. establishes the Combatting Iron Deficiency Anemia project.

1977—A.I.D. funds initial research on vitamin A fortification of MSG in the Philippines.

1977—A.I.D. sponsors the International Nutritional Anemia Consultative Group (INACG) to coordinate the efforts of donors and foster the exchange of ideas and information.

1979—A.I.D. funds WHO surveys in the Near East and Africa, documenting widespread vitamin A deficiency in Africa.

1980—A.I.D. funds International Center for Epidemiologic and Preventive Ophthalmology (ICEPO) of Johns Hopkins University as research and technical assistance resource center.

1984—Indonesia field research published, establishing links between vitamin A and morbidity and mortality.

1985—A.I.D. increases support of vitamin A activities by ten-fold for country programs in Asia, Africa, and Latin America.

1987—A.I.D. expands the Combatting Iron Deficiency Anemia project to provide technical assistance and training, including support for University of Kansas Medical Center.

1988—A.I.D. establishes VITAP to provide technical assistance to PVOs in their efforts to reduce vitamin A deficiency.

1988—A.I.D. funds development of new technology for iron supplementation.

1988—A.I.D. reviews and recommends an increase in vitamin A levels of U.S. food donations.

1989—The field support component of the Vitamin A for Health project is initiated through VITAL to assist field missions and regional bureaus in expanding programs worldwide.

1990—INACG meeting presents new technologies for iron fortification and develops a consensus for support of a global initiative for iron fortification.

1990—A.I.D. reviews and recommends a doubling of iron levels in U.S. food donations.

1991—A.I.D. Vitamin A Strategy is developed as well as regional strategies for the elimination of vitamin A deficiency by the year 2000.

1991—A.I.D. cosponsors "Ending Hidden Hunger: A Policy Conference on Micronutrient Malnutrition," October 10-12, 1991, in Montreal, Canada.

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