REVIEW OF LITERATURE

The literature pertaining to the study entitled "Haemopoietic Micro-nutrient Fortified Rice on the Nutritional Status and Cognitive Performance of Adolescents" is reviewed under the following headings:

A. NUTRITION DURING ADOLESCENCE

B. MICRO-NUTRIENTS AND COGNITIVE PERFORMANCE

C. CAUSES AND EFFECTS OF MICRO-NUTRIENT DEFICIENCIES

D. PREVALENCE OF MICRO-NUTRIENT DEFICIENCIES

E. STRATEGIES TO PREVENT MICRO-NUTRIENT DEFICIENCIES

A. NUTRITION DURING ADOLESCENCE

According to WHO (2006) good nutrition is essential to good health throughout life, beginning with parenteral life and extending through old age. World Health Organisation defines health as the “state of complete physical, mental and social well being and not merely the absence of disease and infirmity” wellness implies a positive dynamic state motivating a person to seek a higher level of functioning. Hence, nutrition contributes to productivity and poverty reduction. Nutrition and economic development have a two-way relationship. Improved nutrition drives stronger economic growth and improved economic development contributes to improved nutrition.

Singh (2012) explains that the important role of nutrition is to promote health, prevent, treat and control disease conditions. Reduced intake of specific nutrients leads to nutritional deficiency disorders, such as protein-energy malnutrition, vitamin A deficiency or anaemia, which in turn leads to degenerative diseases.

Pandav (2013) opines that malnutrition (both under- and over nutrition) is currently one of the biggest challenges being faced by the modern world. Micro-
nutrient deficiencies, more commonly referred to as “hidden hunger”, form a significant component of burden of malnutrition worldwide, more so in developing countries like India. Deficiencies of iodine, iron, folic acid, vitamin A and zinc are the leading five causes of micro-nutrient deficiencies which constitute a global public health problem.

According to WHO (2010) adolescence, the second decade of life is a period in which an individual undergoes major physical and psychological changes. It presents a window of opportunity to set the stage for healthy and productive adulthood and to reduce the likelihood of problems in the years that lie ahead. At the same time, it is period of risk: a period when health problems that have serious immediate consequences can occur or when problem of behaviours that could have serious adverse effects on health in the future are initiated.

Anabwani (2015) says that there is no agreed definition of adolescence; the WHO defines it as ages 10-18, while the American Academy of Pediatrics defines it as 13-18 years. The overriding fact is that this period is characterised by rapid, physical, emotional, social, sexual, psychological, development and maturation. Because adolescence is characterised by increasing maturity and a trend towards autonomy and independence, adolescents are generally curious, adaptive and open to new ideas.

Koushik (2014) classifies, adolescent in to two groups they are the Early adolescence: 10-14 yrs and the Late adolescence: 15-19 yrs. There are about 1.2 billion adolescents in the world, which is equal to 1/5th of the world’s population and their numbers is increasing. Out of these, 5 million adolescents are living in the developing countries. India’s population has reached the 1 billion mark, out of which 21 per cent are the adolescents.

Adolescents are not a homeogenous population. The transition from childhood to adulthood involves dramatic physical, sexual, psychological and social developmental changes, all taking place at the same time. In addition to opportunities for development, this transition poses risks to their health and well-being.
Anabwani (2015) explains that two key reasons for interest in nutrition issues among adolescents. In many developing countries their demographic slice is much larger. This large number makes them important as a group as the future economic prospects of the country will depend on the health and education of adolescents today. Secondly, adolescence provides an opportunity to nurture the life-style habits necessary for a healthy productive life which avoids or reverses the current trend towards obesity and premature cardiovascular disease.

Muzammil et al., (2010) conclude that nutritional deficiencies play an important role in the overall health status of adolescents and are different from those of older adults. Due to lack of accurate information and proper guidance, adolescents are prone to various nutritional morbidities. Vitamin B2 deficiency was observed in 2.5 per cent adolescents and Vitamin A deficiency as almost double in boys (1.7%) than in girls (0.9%). As maximum bone growth occurs during this period adolescents are prone to calcium deficiency and increased tendency to bone fracture. Later on in life calcium deficiency in adolescence is associated with high post-menopausal bone loss. These deficiencies and effects can be reversed by adequate intake of calcium. Studies have also reported a positive impact of zinc on linear growth among adolescents with zinc deficiency – particularly boys.

Anabwani (2015) states that iodine deficiency is still an issue in parts of the world without access to iodised salt. To prevent the deleterious mental effects of iodine deficiency on the foetus, normal iodine status must be achieved prior to pregnancy; and for this to happen adolescents, particularly girls, should be targeted in places where iodine deficiency is endemic. Although Vitamin A deficiency has in the past been seen as primarily a problem of children under the age of five years, it is now recognised as common among adolescent girls and it is entangled with iron deficiency.

B. MICRO-NUTRIENTS AND COGNITIVE PERFORMANCE

Carayannis (2000) defines cognition as the intellectual process by which one becomes aware of, perceives, or comprehends ideas. Cognitive function embraces the quality of knowing, which includes all aspects of perception, recognition, conception, sensing, thinking, reasoning, remembering and imagining.
Clark et al. (2010) and Engle (2010) express that cognition represents a complex set of higher mental functions served by the brain, and includes attention, memory, thinking, learning, and perception. Cognitive development in pre-schoolers is predictive of later school achievement. Cognitive development is influenced by many factors, including nutrition. Memory plays a pivotal role in the cognitive development of the children. Good memory skills are essential for a successful schooling experience.

McLeod (2007) says that short-term memory is the capacity for holding a small amount of information in mind in an active, readily available state for a short period of time. Long-term memory is memory in which associations among items are stored, as part of the theory of a dual-store memory model. Long-term memory differs structurally and functionally from short-term memory; while short-term memory persists for only about 20 to 30 seconds, information can remain in long-term memory indefinitely. Long-term memory is an important aspect of cognition what children remember is more often not used as the yardstick to judge what they have learned. If they perform poorly on a test because they cannot retrieve what they know from long-term memory in order to answer test questions, the assumption usually is that learning has not taken place. This can happen when children are undernourished.

According to Cherry, (2012) attention refers to how an individual actively processes specific information present in the environment. Attention allows one to "tune out" information, sensations and perceptions that are not relevant at the moment and instead focuses the energy on the information that is important.

Kennedy (2012) found that twelve weeks of supplementation with vitamins and minerals boosted the attention scores of children. Parker, 2004 views that the children with more adequate diets score higher on tests of factual knowledge than those with less adequate nutrition. For instance, studies in Honduras, Kenya and the Philippines show that the academic performance and mental ability of pupils with good nutritional status are significantly higher than those of pupils with poor nutritional status, independent of family income, school quality and teacher ability.
Holland (2012) finds links between nutrition and brain development, cognitive function, curiosity, behaviour, communication and social skills. Hence good nutrition during childhood lays the foundation for lifetime health, strength and intellectual vitality. Vinod (2011) put forth that the nutritional status of a community particularly of its children has been recognized as an important indicator of national development.

A tremendous impact on every aspect of child development, both physical and mental development. While physical development is important, cognitive development side by side will ensure a balanced growth of the individual. Proper nutrition is essential for learning, thinking, and cognitive perception. Micro-nutrient malnutrition, also known as hidden hunger, reduces learning and cognitive ability; impairs growth; reduces immunity; decreases working capacity; causes several pregnancy complications, blindness, and goitre; and raises the risk of mortality. The populations most at risk of such deficiencies are infants and children, women of reproductive age, pregnant women, and the elderly. 2–5 Lack of dietary diversity (i.e., monotonous diets), poor mineral bioavailability in plant foods, incidence of illness and disease and increased physiological demands are the main contributors to micro-nutrient deficiencies.

According to National Family Health Survey 3 (NFHS) (2005-06), 11 per cent children in India are malnourished out of 15.9 per cent children under the age of five years. Malnutrition disrupts growth and weakens the mental development of children, producing less healthy and less productive adults. Malnutrition in early childhood can further affect school aptitudes, school enrolment and cognition among children (WHO, 2004). Moderate and severe malnutrition was also observed between 11-13 and 13-15 age groups of girls in Tamil Nadu (Krishnan et al., 2012).

According to Stettler et al., (2011) the overall observations demonstrate that even moderate degree of malnutrition influences the IQ scores and its effect is of a higher magnitude on immediate memory, visual perception, and visual motor integration as compared to verbal reasoning and comprehension. Upadhyay et al.,
(1989) studied the relationship between malnutrition and intellectual performance among 1336 rural primary school children of 6-8 years. A child with a poor diet may experience fatigue and be unable to fully participate in learning at school. Also, poor nutrition can make the child more likely to become sick and miss school.

Aqaqolq et al., (2007) found that Iron Deficiency Anaemia (IDA) in children has been associated with retardation in growth and the cognitive development. Bellisle, (2004) did a number of well-designed studies which suggested a potential role of certain nutrients, or elements of eating patterns in cognitive functioning in children and adolescents. Iron Deficiency Anaemia (IDA) in children has been associated with retardation in growth and the cognitive development.

Eilander et al., (2010) summarized that the micro-nutrient deficiencies often coexist and synergistic effects of micro-nutrients on physical functions may indirectly affect cognition, supplementing children with multiple micro-nutrients could have greater advantages over single micro-nutrient supplementation

The brain is sensitive to moment-to-moment metabolic changes associated with the pattern of meals and fasting, and also to long-term nutritional status. In several instances, it has been revealed that the clearest effects of nutritional manipulations on cognitive efficiency and behaviour are obtained in young people with poor nutritional status. Corrective nutritional interventions in these unfortunate cases can only reverse the negative impact of inadequate diets. This underlines the unquestioned necessity of making adequate nutrition available to all youngsters, to prevent intellectual and behavioural problems of potentially long-lasting negative influence.

Learning is an important factor among the three factors affecting their cognitive development such as genes, nutrition and environment. Intelligence plays a vital role in the cognitive development. A person who is intellectually superior performs well in the academic examinations and score good marks.

According to Bainbridge (2012) Intelligence is the ability to learn about, learn from, understand, and interact with one’s environment. This general ability
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consists of a number of specific abilities, namely adaptability to a new environment or to changes in the current environment, capacity for knowledge and the ability to acquire it, capacity for reason and abstract thought, ability to comprehend relationships, ability to evaluate and judge and capacity for original and productive thought.

Field et al., (2007) state that Iodine is unique among micro-nutrients in its effect on brain development and cognition, and small differences in average IQ at the group level could have large effects on social and economic outcomes.

Essential fatty acids play a central functional role in brain tissue. They are not only the basic components of neuronal membranes, but they modulate membrane fluidity and volume and thereby influence receptor and enzyme activities in addition to affecting ion channels. Essential fatty acids are also precursors for active mediators that play a key role in inflammation and immune reaction. They promote neuronal and dendritic spine growth and synaptic membrane synthesis, and hence influence signal processing, and neural transmission. In addition, essential fatty acids regulate gene expression in the brain (Souza et al., 2011)

According to Greene (2010), ‘Brain – Specific’ nutrients include n-3 polyunsaturated fatty acids, iodine, copper and iron. Deficiency of any one of these nutrients may cause permanent impairment in neurodevelopment that can be prevented by inclusion in the diet of sufficient amounts of these nutrients. A large number of studies have suggested that low DHA levels are associated with problems in intelligence, vision, and behavior.

Schuchardt et al., (2010) finds that the effect of essential fatty acids, particularly long chain poly unsaturated fatty acids (LCPUFA), on cognitive brain development. Of the human brain’s dry weight 60 per cent is comprised of lipids, of which 20 per cent are docosa hexaenoic acid (DHA; which is an omega-3 fatty acid) and arachidonic acid (AA; an omega-6 fatty acid). These represent the two core fatty acids found in gray matter (Benton,2010; DeSouzaetal.,2011). Furthermore, the supply of LCPUF as from food, especially the omega-3 fatty
acids, including DHA and eicosapentaenoic acid (EPA), is frequently inadequate for children as well as for adults.

In recent years, there has been an increasing interest in the association between vitamin B_{12}, folic acid, choline metabolism, and cognitive development. Folate affects neural stem cell proliferation and differentiation, decreases apoptosis, alters DNA biosynthesis, and has an important role in homocysteine and S-adenosylmethionine biosynthesis. It is believed that choline has similar roles in brain development as folate (Zeisel, 2009; Zhang et al., 2009).

Nyardi et al., (2013) underlines that the majority of studies, which have investigated the association between nutrition and cognitive development, have focused on individual micro-nutrients, including omega-3 fatty acids, vitamin B_{12}, folic acid, zinc, iron, and iodine. The evidence is more consistent from observational studies, which suggest these micro-nutrients play an important role in the cognitive development of children. However, the results from intervention trials of single nutrients are inconsistent and inconclusive, prompting the need for better controlled and more adequately powered studies in the future. It is plausible that children living in poor countries may encounter more multiple micro-nutrient deficiencies, as opposed to children living in rich countries who are reasonably well nourished (and where a small deficiency in one nutrient may not result in measurable, long-term change in cognitive outcomes, due to compensation over time). These are important considerations, because nutrients do not act alone; rather, they have in some contexts synergistic and in other contexts antagonistic effects with each other. Individuals consume combinations of food and poor overall diet can cause multiple macro- and micro-nutrient deficiencies and imbalances. If an overall healthy diet synergistically enhances cognitive development in children, then public health interventions should focus on the promotion of overall diet quality rather than isolated micro-nutrients or dietary components consumed by children and adolescents.

C. CAUSES AND EFFECTS OF MICRO-NUTRIENT DEFICIENCIES

Muthayya (2013) reports that single Micro Nutrient Deficiencies (MNDs) rarely happen in isolation; more often, multiple MNDs are occurring
simultaneously. Multiple MNDs appear to be mainly driven by a lack of food security, defined by the Food and Agriculture Organization (1996) at the World Food Summit as follows: ‘when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life’. As per Mayo-Wilson et al., (2014), many factors contribute to food security and MNDs, including lack of available quality and diversity of foods, poverty in certain population groups, lack of access to health care and nutrition education, subsistence farming practices, volatile food prices, urbanization, high rates of infection (both acute and chronic), and issues with sanitation, climate change, and access to potable water (Stewart et al., 2013).

Muthayya et al., (2013) opine that micro-nutrient deficiencies are only one form of under nutrition which are not visible. Other forms of under nutrition are more readily visible and, for this reason, MNDs are often referred to as hidden hunger. At the most basic level, MNDs, like all forms of under nutrition, occurs due to insufficient intake or sufficient intakes combined with impaired absorption due to infection, disease or inflammation (UNICEF, 2013). The determinants of under-nutrition are well illustrated by UNICEF in Figure 1.
UPDATED UNICEF CONCEPTUAL FRAMEWORK FOR THE DETERMINANTS OF UNDERNUTRITION

FIGURE 1
Bhatta et al., (2013) list the underlying causes that contribute to the immediate causes include food insecurity, inadequate care or feeding practices and an unhealthy environment with inadequate access to health services. Liu et al., (2012) stress that nutritional status is greatly impacted by infection. Infection is the leading cause of child mortality. Acute respiratory infection and diarrhoea are the most common causes of infant mortality, and MNDs contribute greatly to the immune response. Under nutrition is the leading cause of immunodeficiency worldwide.

According to Millennium Development Goals-MDG (2000) the basic root cause of most under nutrition is poverty. As a result, low- and middle-income countries have the highest burden of MNDs; however, MNDs exist even in certain population groups in higher-income countries. The United Nation's Millennium Development Goals include eradicating extreme poverty and hunger as their priority goal. Like poverty, under nutrition and MNDs often occur as part of an intergenerational cycle (Figure 2).

The causes of micro-nutrient deficiencies are

- Monotonous diet resulting in low micro-nutrient intake, and poor bioavailability, especially of minerals
- Low intake of animal source foods
- Low prevalence of breastfeeding
- Low micro-nutrient density of complementary foods
- Increased physiological demands for growth during pregnancy and lactation.
- Increased demand due to acute infection (especially if infection episodes are frequent) chronic infection (e.g. tuberculosis, malaria and HIV/AIDS) and disease (e.g. Cancer).
- Poor general nutritional status, in particular, protein–energy malnutrition.
- Malabsorption due to diarrhoea or the presence of intestinal parasites (e.g. Giardia lamblia, hookworms).
- Increased excretion (e.g. due to schistosomiasis)
- Seasonal variations in food availability, food shortages
- Social deprivation, illiteracy, low education
- Poor economic status and poverty
THE CONCEPTUAL FRAMEWORK FOR THE CYCLE OF MICRO-NUTRIENT INADEQUACIES ACROSS THE LIFE SPAN

FIGURE 2
NIN (2011) reported that haemopoietic micro-nutrients are iron, zinc, folate, vitamin A, C, B₆, B₁₂, and B₂. Micro-nutrient deficiencies such as Vitamin A Deficiency (VAD), Iron Deficiency Anemia (IDA), Iodine Deficiency Disorders (IDD) and vitamin B-complex deficiencies are the nutritional problems frequently encountered, particularly among the rural poor and urban slum communities.

West *et al.*, (2012) revealed that iron is a mineral that is an essential component of hemoglobin, myoglobin, enzymes, and cytochromes and is necessary for oxygen transport and cellular respiration. Iron also is critical for optimal growth and cognitive function. Two forms of iron exist, namely heme and nonheme. Heme iron is found in animal sources, whereas nonheme iron is found in plants and used in fortification. Neither form of iron is highly bioavailable; heme iron bioavailability is estimated to be 12-25%, and nonheme iron is <5% bioavailable; however, with the exception of menstruating and pregnant women, iron in vivo is very highly conserved. Iron deficiency is the most common MND in the world, affecting more than 30% of the world’s population, an estimated 2 billion people.

Lozoff *et al.*, (2013) emphasize that anaemia is estimated to contribute to 20 per cent of maternal deaths. Children born to iron-deficient mothers are more likely to have low iron stores, to suffer from impaired physical and cognitive development, and to have suboptimal immune systems. Early-life iron status substantially influences human potential at the individual and country level. Iron deficiency may also be associated with enhanced absorption of environmental metal toxins such as cadmium.

WHO (2014) states that anaemia has multiple causes that very often coexist; it can result from parasitic infections, inflammatory disorders, inherited disorders of haemoglobin structure, or vitamin and mineral deficiencies, including iron and vitamins A, B₁₂ and folate. At least half the burden of anaemia is associated with iron deficiency.
The reasons for the high incidence of anaemia among the adolescents

- a low intake of haem iron (which is present in meat, poultry and fish)
- an inadequate intake of vitamin C (ascorbic acid) from fruit and vegetables (the presence of vitamin C enhances the absorption of iron from the diet)
- poor absorption of iron from diets high in phytate (including legumes and cereals) or phenolic compounds (present in coffee, tea, sorghum and millet)
- periods of life when iron requirements are especially high (i.e. growth and pregnancy)
- heavy blood losses as a result of menstruation, or parasite infections such as hookworm, ascaris and schistosomiasis.
- as mentioned above, acute or chronic infections, including malaria, can also lower haemoglobin concentrations. The presence of other micro-nutrient deficiencies, especially of vitamins A and B₁₂, folate and riboflavin, also increases the risk of anaemia and
- the dietary habits of a population group strongly affect the bioavailability of both dietary iron and added fortificant iron. Although the efficiency of iron absorption increases substantially as iron stores become depleted, the amount absorbed from foods, especially where diets are low in meat, fish, fruit and vegetables, is not enough to prevent iron deficiency in many women and children, especially in the developing world.

Iron deficiency causes anaemia and disrupts optimal function of both the endocrine and immune systems. Iron deficiency is particularly common during pregnancy because of increased requirements for fetal growth and development. Maternal iron deficiency is associated with low birth weight, premature delivery, and a host of perinatal complications, especially hemorrhage.

Carlson et al., (2012) expressed that the main consequences of iron deficiency are anaemia, impaired cognitive and physical performance, and increased maternal and child mortality.
Benoist *et al.*, (2008) state that iron deficiency has been shown to reduce physical endurance, even in the absence of anaemia, and severe anaemia has been associated with an increased risk of both maternal and child mortality. Iron supplementation can reverse the adverse effects of iron deficiency on work capacity and productivity, and on pregnancy outcome and child development.

Sonkaria *et al.*, (2012) ensure that the iron is required by the enzymes that synthesize thyroxine, and thus a low iron status may have implications for iodine metabolism. Studies in Côte d’Ivoire have demonstrated that recovery from goitre after iodine treatment is slower in iron-deficient individuals.

Vitamin A is a fat-soluble vitamin that has multiple roles in the body including vision, cell differentiation, immune function, reproduction, and organ and bone formation and growth. Vitamin A comes from animal sources in the diet preformed as retinol or retinyl esters, or from provitamin A carotenoids found in plant sources. Provitamin A carotenoids, which exhibit differential vitamin A activity, are converted to the active forms of the vitamin (retinal and retinoic acid) for use by the body.

West *et al.*, (2012) put forth the fact that vitamin A deficiency (VAD) has been associated with increased rates and severity of infections and is a primary cause of childhood morbidity and mortality in the developing world, particularly in Africa and Southeast Asia. VAD is the leading cause of preventable blindness in children. VAD causes xerophthalmia, a series of ocular manifestations like night blindness, Bitot’s spots, and corneal ulcerations and lesions.

Muthayya *et al.*, (2013) underline that vitamin A deficiency affects visual function, indicators of vitamin A status have traditionally relied on changes in the eye, specifically night blindness and xerophthalmia.

Zimmermann *et al.*, (2009) explain that iodine is a trace mineral and its primary function is in the synthesis of thyroid hormone. Approximately 60% of the total body pool of iodine is stored in the thyroid gland. Tayie *et al.*, (2010) state that thyroid hormones are essential for optimal fetal and postnatal central nervous system growth and development.
It is intuitive to think that thyroid hormones may serve as a biomarker of iodine status; however, thyroid hormones, with the exception of thyroglobulin, do not appear to be adequately sensitive to change in iodine status (Vejbjerget al., 2009). Andersson et al., (2010) observe that the pregnant females and infants (<24 months of age) are the population groups at highest risk of iodine deficiency. As previously stated, in pregnancy, requirements are greatly increased, and infants have the highest requirements per kg of body weight of any age group. Exclusively breastfed infants may also be at risk if not provided iodine in complementary foods. While iodine is found in breast milk, its concentration is dependent on maternal intake and status.

According to Zimmermann et al., (2008) and Pandav (2013), IDD represent a spectrum of diseases affecting the entire life course. From infancy to adulthood, IDD includes goiters, impaired mental function, and hypo or hyperthyroidism. At the most severe form, in utero iodine deficiency can result in cretinism. The spectrum of diseases includes goitre, cretinism, hypothyroidism, brain damage, abortion, still birth, mental retardation, psychomotor defects and hearing and speech impairment. Majority of consequences of IDD are invisible and irreversible but at the same time preventable.

Pandav (2013) revealed that Iodine Deficiency Disorders (IDD) constitute the single largest cause of preventable brain damage worldwide. Majority of consequences of IDD are invisible and irreversible but at the same time these are preventable. In India, the entire population is prone to IDD due to deficiency of iodine in the soil of the subcontinent and consequently the food derived from it. However, an estimated 350 million people do not consume adequately iodized salt and, therefore, are at risk for IDD. Of the 325 districts surveyed in India so far, 263 are IDD-endemic. The current household level iodized salt coverage in India is 91 per cent with 71 per cent households consuming adequately iodized salt.

The spectrum of iodine deficiency disorders are presented in the Table 1.
Folate is a generic term for multiple forms of the essential B vitamin. Folate naturally occurs in foods, whereas folic acid is a synthetic form of the vitamin that is used in fortified foods and in dietary supplements. Folic acid is much more bioavailable than folate naturally occurring in foods and when ingested is converted by dihydrofolate reductase to the dihydrofolate and then the tetrahydrofolate form of folate; these reduced compounds are identical to those that would arise from ingestion of natural folate. Folate is essential for synthesis of purines and thymidylate and, therefore, is involved in DNA synthesis, stability, and repair. Folate is also involved in one carbon metabolism and, as such, can alter DNA methylation, which is an important epigenetic determinant in gene expression, in the maintenance of DNA integrity, and in the development of mutations.
Folate deficiency causes megaloblastic or macrocytic anemia and increases the likelihood for pregnancies affected by neural tube defects. The global prevalence of anemia secondary to folate deficiency is very low. Folate deficiency in pregnancy has also been associated with low birth weight, preterm delivery, and fetal growth retardation (Tamura et al., 2010).

Pfeiffer et al., (2007) conclude that Folate deficiency can be determined by serum, plasma, or erythrocyte folate concentrations. Folate deficiency is very low in countries with mandatory or voluntary folic acid fortification programs.

Zinc is an essential mineral that is involved in multiple aspects of cellular metabolism. Zinc is required for the activity of more than 200 enzymes, and it is critical for immune system function, cell division, and protein and DNA synthesis. Zinc is also required for normal growth and development from in utero until puberty. The human body has no long-term storage system for zinc, so consistent dietary intake is needed to sustain all of these functions and maintain the relatively small exchangeable zinc pool. Because of its diverse functions in vivo, it has been difficult to develop a single biomarker of zinc status; plasma zinc concentrations have been used, but this biomarker is nonspecific. Zinc is primarily found in animal products and seafood.

Zinc is essential for growth and development and has a specific role in cellular metabolism especially during pregnancy, childhood and adolescence. Deficiency of dietary zinc leads to negative impact on immunity, wound healing, protein synthesis, metabolic and physiological functions.

Deficiency in zinc is thought to be one of the primary causes of morbidity in developing countries and, yet, surprisingly little is known about the status of the world. Given the issues concerning the assessment of zinc status by biomarkers, estimates of inadequacy are largely based on the prevalence of child stunting, estimates of dietary intakes, and the availability of zinc from the food supply.
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Similar to iron, zinc absorption is impaired by phytates, fiber, and lignins, all of which impair the bioavailability from non-animal sources of zinc. Calcium and casein may reduce the bioavailability of zinc from cow’s milk. Zinc is present in human breast milk. (King, 2011).

Penland et al., (1999) report that the deficiency of zinc during the initial stages of development can lead to brain abnormalities and altered neural functions due to the induction of oxidative stress and deregulation of signaling proteins. Adequate zinc levels are needed to maintain brain function and to prevent neurological diseases. In Mexican-American children from Texas, it has been found that zinc supplemented school age children demonstrate superior neuropsychological performance, particularly reasoning, when compared with controls. Despite the fact that brain represents only ~2 per cent of the total body weight, amazingly, the brain consumes 20 per cent of daily energy intake. For this reason, it is essential that enough food with adequate nutrients namely protein, iron, iodine, folate, vitamins B₆, B₁₂ and zinc are taken to keep the brain functioning optimally.

Zinc status has been associated with reduced incidence, severity, and mortality due to diarrhoea and respiratory and malarial infection as summarized by Patel et al., (2010) and Black et al. (2013) found that infection is known to compromise dietary intake and micro-nutrient absorption, and diarrhoea can contribute to losses in key micro-nutrients.

Iodine deficiency during childhood reduces somatic growth and cognitive and motor function (Zimmermann, 2009). Deficiency in vitamin A and zinc are particularly dangerous for children who are fighting measles, diarrhoea and malaria. About 20 to 24 per cent of deaths from these three diseases are attributed to inadequate vitamin A or zinc (Black et al., 2008). This high morbidity among this population is due to parasitic infections, malnutrition, micro-nutrient deficiencies and other diseases (Rai et al., 2009).

F. PREVALENCE OF MICRO-NUTRIENT DEFICIENCIES

According to Muthayya et al., (2013) global hidden hunger indices for iron, vitamin A, and zinc together and determined that 18 of the 20 countries with the
highest burden of multiple MNDs are in Africa, with Afghanistan and India (WHO region Asia) completing the list. Iodine may be the exception to the clustering of MNDs, and iodine deficiency is region specific and does not necessarily track with countries with a high hidden hunger. However, deficiency in other micro-nutrients, like selenium, iron, and vitamin A, can exacerbate iodine deficiency by altering thyroid function.

According to Global Alliance for Improved Nutrition (GAIN) (2014) India has the high burden of micro-nutrient deficiency diseases such as anaemia, Vitamin A deficiency, iodine deficiency disorders etc. Micro-nutrient deficiency is prevalent in all age groups. As per WHO (2008) the terms, "iron deficiency" and "iron-deficiency anaemia" are often used synonymously although they are in fact not the same conditions. About 40% of the world’s population (i.e. more than 2 billion individuals) is thought to suffer from anaemia, i.e. low blood haemoglobin.

According to WHO (2007) Prevalence of anaemia in India and neighbouring countries covering almost half the world’s population, estimated the prevalence of anaemia worldwide at 25 per cent. Although the prevalence of anaemia is estimated at 9 per cent in countries with high development, in countries with low development the prevalence is 43 per cent. In absolute numbers anaemia affects 1.62 billion people globally with about 293 million children of preschool age, 56 million pregnant women, and 468 million non-pregnant women estimated to be anaemic. Africa and Asia account for more than 85 per cent of the absolute anaemia burden in high-risk groups and India is the worst hit.

Anaemia is estimated to contribute to more than 115,000 maternal deaths and 591,000 perinatal deaths globally per year. Analysis of data on global prevalence shows that anaemia is disproportionately concentrated in low socioeconomic groups, and that maternal anaemia is strongly associated with child anaemia. Prevalence anaemia is India and neighbouring countries is presented in Table 2 and in different age groups is presented in Table 3.
TABLE II

PREVALENCE OF ANAEMIA IN INDIA AND NEIGHBOURING COUNTRIES

<table>
<thead>
<tr>
<th>Country</th>
<th>Proportion of population with anaemia (Hb &lt;11 g/dl)</th>
<th>Public health problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>47.0</td>
<td>Severe</td>
</tr>
<tr>
<td>Bhutan</td>
<td>80.6</td>
<td>Severe</td>
</tr>
<tr>
<td>India</td>
<td>74.3</td>
<td>Severe</td>
</tr>
<tr>
<td>Nepal</td>
<td>78.0</td>
<td>Severe</td>
</tr>
<tr>
<td>Pakistan</td>
<td>50.9</td>
<td>Severe</td>
</tr>
<tr>
<td>Srilanka</td>
<td>29.9</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

Source: WHO Glosource: Global Database on Anaemia

TABLE III

PREVALENCE OF ANAEMIA IN DIFFERENT AGE GROUPS

<table>
<thead>
<tr>
<th>Age groups</th>
<th>Prevalence of anaemia (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children (6-35 months)</td>
<td>79</td>
</tr>
<tr>
<td>Children (6-59 months)</td>
<td>69.5</td>
</tr>
<tr>
<td>All women (15-49 years)</td>
<td>55.3</td>
</tr>
<tr>
<td>Ever married women (15-49 years)</td>
<td>56</td>
</tr>
<tr>
<td>Pregnant women (15-49 years)</td>
<td>58.7</td>
</tr>
<tr>
<td>Lactating women (15-49 years)</td>
<td>63.2</td>
</tr>
</tbody>
</table>

Adolescent Girls

12-14 years                         68.6
15-17 years                         69.7
15-19 years                         55.8

Adolescent Boys                     30

Source: NFHS-3*National Nutrition Monitoring Bureau Survey (NNMBS), 2006

These average figures obscure the fact that iron deficiency and iron-deficiency anaemia are even more prevalent in some parts of the world, especially in the Indian subcontinent and in sub-Saharan Africa, where, for example, up to 90% of women become anaemic during pregnancy. Anaemia is a common malady in the developing world with wide spread prevalence especially among the adolescent girls. WHO (2014) has estimated that the global prevalence of anaemia in non-pregnant women as 30.2 per cent.
It is generally assumed that, on average, around 50% of the cases of anaemia are due to iron deficiency, as opposed to malaria (which causes anaemia because the malaria parasite destroys erythrocytes), the presence of infection or other nutrient deficiencies. However, the proportion is probably higher in infants and preschool-aged children than in older children or women and is likely to vary by location.

Studies by Koushik et al., (2014) on the prevalence and the severity of the anaemia among the adolescent girls showed that the prevalence of anaemia was 77.33% (with that of severe anaemia being 12.06%, that of moderate anaemia being 50.86% and that of mild anaemia being 37.06%). Majority of the girls had the moderate anaemia. The prevalence of anaemia was considerably high among the adolescent girls who belongs to the lower socio-economic status. There was a significant association of anaemia with the socio-economic status.

The high risk areas of iron deficiency, vitamin A and iron deficiency and iodine, vitamin A & iron deficiency are shown in Figure 3.

Source: USAID

HIGH RISK AREAS OF IRON, VITAMIN A AND IODINE DEFIENCIES

FIGURE 3

The WHO estimates that 250-500 million children are blind because of VAD, and half of these children will die within a year of vision loss. VAD is also common in pregnancy in lower-income countries with estimates ranging from 10 to 20%. Very little is known about older children and adults with regard to vitamin A
status; however, because VAD tends to cluster in families, communities, and regions, we can assume that vitamin A status is low in areas with child and pregnancy burden. Subclinical VAD affects far greater numbers of individuals, particularly in Africa and Asia (WHO, 2009).

Worldwide, about 3 million preschool-aged children present ocular signs of VAD. Vitamin A deficiency is, however, more commonly assessed using serum or plasma retinol levels. WHO estimates that 254 millions of preschool-aged children throughout the world have low serum retinol levels and can, therefore, be considered to be clinically or sub-clinically vitamin A deficient. In the developing world, prevalence rates in this age group range from 15% up to as high as 60%, with Latin America, the Eastern Mediterranean and the Western Pacific being at the low end of this range, and Africa and South-East Asia occupying the high end. The prevalence of night blindness is also high among pregnant women in many poor regions of the world, with rates varying between 8% and 24%. Night blindness tends to be accompanied by a high prevalence of low concentrations of retinol in breast milk (<1.05 μmol/l or 30 μg/dl). (Regil, 2011).

Globally, ~2 billion are estimated to have inadequate iodine status (Andersson et al., 2012). As many as half of the European population (52%, 459.7 million people) is estimated to have inadequate iodine status and more than 500 million individuals are affected in Southeast Asia. While the group of highest concern is pregnant females, we have no global estimation of the burden of iodine deficiency in this group. Approximately 30% (241 million) of the world’s school-aged children have insufficient iodine intakes (UNICEF, 2007).

According to recent WHO estimate that some 1989 million people have inadequate iodine nutrition. The WHO regions, ranked by the absolute number of people affected are, in decreasing order of magnitude, South-East Asia, Europe, the Western Pacific, Africa, the Eastern Mediterranean and the Americas. In some parts of the world, for example, in parts of eastern and western Europe, iodine deficiency, in its subclinical form, is re emerging, having previously been
eliminated. This underscores the need to sustain efforts to control iodine deficiency on a global scale.

Nutritional anaemia due to iron and folic acid deficiency is a major global public health problem. South Asia ranks among the regions, which have the highest prevalence of anaemia in the world and India perhaps has the highest prevalence of anaemia among the South Asian countries (Koushik et al., 2014).

Globally, only about 30% of women take folic acid supplements prior to conception. No good estimates of global folate deficiency exist for those considered to be of highest risk: women of reproductive age, pregnant females, and young children (Mclean, 2008).

Globally, it is estimated that 17.3% of the population has inadequate zinc intakes, with the highest estimates in Africa (23.9%) and Asia (19.4%). Pregnant females and their young children are the highest-risk groups for zinc deficiency. Of global concern are deficiencies in iron, vitamin A, zinc, folate, and iodine. The World Health Organization (WHO) reported that over two billion people are at risk of vitamin A, iodine and/or iron deficiency, with the most

STRATEGIES TO PREVENT MICRO-NUTRIENT DEFICIENCIES

Branca et al, (2015) estimate that every year the lives of around 50 million children are put at risk because they are dangerously thin from acute undernutrition, while the long term health of more than 40 million children is threatened because they are overweight. Two billion people suffer from vitamin and mineral deficiencies, but overweight and obesity are key contributors to the non-communicable diseases that account for almost two thirds (63%) of adult deaths globally. These different forms of malnutrition—undernutrition, overweight and obesity, and micro-nutrient deficiencies—now affect people across the same communities and harm people of all ages.

Branca, (2015) states that improving nutrition presents a key opportunity to improve health. As the UN secretary general launches his second Global Strategy for Women’s, Children’s and Adolescents’ Health in September 2015 a
strengthened focus on nutrition is warranted, with special attention to the first 1000 days of life (from pregnancy to the child’s second birthday), pregnant and lactating women, women of reproductive age, and adolescent girls.

Several options exist to combat MNDs, including supplementation, fortification, and food-based approaches like dietary diversification. The choice of intervention strategy or strategies should depend on the cause, severity, and scope of the MND. The intervention strategy should always try to eliminate the root cause and must be considered within the cultural preferences. Understanding the sustainability and feasibility of interventions is critical a priority. Ensuring continued access to the intervention or strategy is of upmost importance depending on the intervention. In general, supplementation is the approach to utilize when an MND is severe and requires a therapeutic approach to treatment, or for the purpose of prevention.

The guidelines recommended for the healthy adolescents are eat many different kinds of food each day, eat enough for growth and physical activity, choose foods low in fat, sugar and salt, choose snacks well, drink plenty every day, not drink alcohol, take part in regular physical activity.

The most conventional and widely practiced strategies used to address micro-nutrient malnutrition are supplementation and food fortification. These strategies do not, however, address the primary cause of poor micro-nutrient status, inadequate dietary intake because of food insecurity, and may not be the most acceptable, accessible, or appropriate strategies for rural and/or ultra-poor households. Complementary strategies are needed in these contexts that support culturally appropriate dietary modification and community- and agriculture-based interventions, with simultaneous efforts to improve capacity and reach of supplementation and fortification.

Hurrel (2002) trace out the history of fortification in 1941, United States was the first country to enrich low extraction wheat with flour with iron and vitamins; by 1965, virtually all white wheat flour and wheat bread and most corn meal (86-94 per cent), grits and macaroni products were fortified with iron. By 1979, most of
the ready to eat breakfast cereals (92 per cent), commercial cereal based weaning foods were fortified. Mandatory enrichment of white wheat flour with iron was introduced in the United Kingdom and Canada in 1953 and many other countries have since introduced either mandatory or voluntary enrichment, usually adding sufficient iron to white wheat flour to restore the level to that in whole grain or 80 per cent extraction flour.

Salgueiro (2002) listed out that the foods that were fortified with wheat flour, rice, sugar, salt, milk, fish sauce and curry powder. Drago (2003) summarizes the Criteria for effective food fortification an adequate selection of food vehicle, the fortification compound, and technical issues related to food formulation and processing.

Guamuch (2014) found that Food fortification is a more long-term strategy to combat MNDs than supplementation. Fortification differs from supplementation in that most of the population is exposed to fortification, whereas supplementation is targeted toward certain individuals or groups. Fortification generally requires policy and procedural changes and engagement of the food industry and, thus, requires substantially more time to implement than supplementation. However, if an MND is widespread, fortification is the tool with the greatest capacity to reach the most within a country. The choice of the food vehicle is equally critical as the amount of fortificant to add; ideally, fortification will enhance the intakes at the lowest tail of the intake distribution without causing excessive intakes among those with already high intakes. Using more than one food vehicle and understanding the current intake patterns have been recommended to avoid excessive intakes of nutrients caused by fortification.

According to Gibson (2006) biofortification is the development of micro-nutrient-dense staple crops using the best traditional breeding practices and modern biotechnology. This approach has multiple advantages: First, it capitalizes on the regular daily intake of consistent large amounts of food staples by all family members. Second, after one time investment to develop seeds that fortify
themselves, recurrent costs are low and germ plasm can be shared internationally. This multiplier aspect of plant breeding across time and distance makes it cost-effective. Third, once in place, the biofortified crop system is highly sustainable. Nutritionally improved varieties will continue to be grown and consumed year after year, even if government attention and international funding for micro-nutrient issues fade. Fourth, biofortification provides a feasible means of reaching the undernourished populations in relatively remote rural areas, delivering naturally fortified foods to people with limited access to commercially marketed fortified foods that are more readily available in urban areas. Biofortification and commercial fortification, therefore, are highly complementary. Finally, breeding for higher trace mineral density in seeds will not incur a yield penalty.

Nestel (2006) says that biofortification may have important spinoff effects for increasing farm productivity in developing countries in an environmentally beneficial way. Mineral-packed seeds sell themselves to farmers because these trace minerals are essential in helping plants resist disease and other environmental stresses. Moreover, a higher proportion of seedlings survive, initial growth is more rapid, and ultimately yields are higher.

Rajasekaran (2013) reveals that an emerging option for enhancing micro-nutrient intakes is by biofortification. Biofortification utilizes recombinant DNA technology or fermentation procedures to alter the micro-nutrient content, but not the appearance, taste, or smell, of an existing food or crop.

The use of nanotechnology to create new delivery systems and storage forms of micro-nutrients is also a rapidly evolving field (Sonkaria S, 2012). Continued monitoring of any widespread food fortification program is necessary. An alternative to fortification of the food supply are home-based fortification systems in which micro-nutrients are added to foods that are already consumed within the home. This strategy, often called ‘home fortification’, avoids the policy and food industry involvement and allows for targeted intervention in individuals in need. Most often, home fortification involves adding multiple micro-nutrients to a semi-solid food prepared in the home. The micro-nutrients generally come in packets or sachets. Home based fortification programs were ongoing in
22 countries as of 2011. In one trial in Pakistan, the use of home fortification with multiple micro-nutrients in children aged 6-18 months was associated with a significant decline in iron deficiency anaemia but was also associated with increased rates of diarrhoea (Soofi, 2013).

WHO has developed **Strategic directions for improving adolescent health in South East Asia Region** that proposes **4S Framework** to strengthen the response of health sector to adolescent health and development, focusing on Strategic information, Supportive policies, Strengthening services, and Strengthening collaboration with other sectors.

- **Strategic Information**: Improving the collection, analysis, interpretation and dissemination of data that are required for advocacy, policies and programmes
- **Supportive evidence-informed policies**: Synthesizing, disseminating and contributing to the evidence base for policies (and programmes) that have an impact on the health and development of adolescents
- **Strengthening services for adolescents**: Increasing young people’s access to, and use of appropriate health services and commodities that respond to a number of priority health conditions
- **Strengthening collaboration with other sectors**: Mobilizing and supporting other sectors to maximize their contributions to adolescent health and development, both what they can do to strengthen the health sector response and what the health sector can do to support their actions.

The health service and intervention addressed in WHO (2014) guidelines are present in Figure 4.
HEALTH SERVICES AND INTERVENTIONS ADDRESSED IN WHO GUIDELINES

FIGURE 4
WHO (2014) report in its document that a weekly supplementation with iron and folic acid in menstruating women has been successfully implemented using different delivery mechanisms in several countries (including Cambodia, Egypt, India, Laos, the Philippines and Viet Nam), reaching over half a million women. In general, the reported compliance has been high, with a decrease in the prevalence of anaemia between 9.3 per cent and 56.8 per cent.

Regil et al., (2011) found that through a Cochrane review of home fortification suggests that home fortification with multiple micro-nutrients is effective for reducing anemia and iron deficiency but cautions that such products be used judiciously in areas with malaria as limited data exist at present. Issues have been raised concerning the compliance to home fortification systems and also concerning an increase in pollution due to the foil-lined packaging needed to preserve the micro-nutrients. While optimal in terms of sustainability, changing the dietary patterns of individuals and communities may be difficult to achieve. Dietary diversification may not be possible due to limited food availability within certain regions. However, resources could be directed towards agricultural practices to change food availability; this is a sustainable mechanism to ensure access to a particular food or foods.

Srinivas et al., (2010) reveal that in a population of children with a high prevalence of anaemia and goitre, iron supplementation improved the response to iodized oil or iodized salt. On the basis of the above findings, it is reasonable to assume that improvements in the iron status of a population may well have benefits for vitamin A and iodine metabolism.

WHO (2007) report shows that routine iron supplementation in pregnancy and infancy are recommended in areas without endemic malaria. Iron supplementation in those with malaria may exacerbate the falciparum-related complications and mortality. Recently, it has been proposed to dovetail efforts with iron nutriture in conjunction with malaria control programs. Fortification programs with iron exist in several countries with the food vehicles of choice ranging from flours, dairy products, condiments, sugar, and salt to infant formulas. Fortification
and supplementation may be appropriate for areas with high concentrations of vegetarians.

Often, VAD occurs in clusters, so prevention and treatment schedules are in place to provide high-dose oral supplementation intermittently (i.e. semi-annually, every 4-6 months, etc.) based on age (beginning at birth), life stage, and severity of deficiency. Vitamin A can also be added as a fortificant to the food supply. For example, in Guatemala, vitamin A is added to sugar in addition to intermittent supplementation programs, together yielding a low rate of VAD determined by serum retinol. Despite the Cochrane reviews limiting maternal, neonatal, and infant vitamin A supplementation in developing countries, continued emphasis should be placed on vitamin A supplementation programs in Southeast Asia given the clearly documented effects on ocular health and mortality (Gogia and Sachdev, 2011 & Haider and Bhutta, 2011).

Supplementation can be daily or intermittently (i.e. 1-2 times per year). Widespread success has been achieved with vitamin A supplementation for the prevention of night blindness and infant mortality; the success is in part due to the intermittent requirements for supplementation (i.e. 1-2 times per year vs. daily). Supplementation as a strategy requires that provision of supplements is feasible and that adequate educational programs are in place to garner compliance. Ideally, supplementation is limited to these purposes because supplementation does not address the root cause of the deficiency. However, supplementation offers a relatively cost-effective short-term solution to MNDs. There are growing concerns that supplemental nutrients may exhibit different physiological responses and absorption than nutrients found in food; this has been noted for folic acid, zinc, and iron.

Vitamin A deficiency leads to impaired vision and affects immunity to individuals, thereby causing the people susceptible to infections. The following studies report of consuming vitamin A fortified rice to combat the deficiency disorders.
Flores et al., (1994) evaluated the children in a day care center who were 11-77 months of age by supplementing with vitamin A fortified rice with 450µg of retinol. Results revealed that children showing vitamin A deficiency with marginal serum retinol concentrations of < 1.05 µmol/l exhibited 100 per cent and 88 per cent positive response in serum retinol concentrations. Relative dose response test was used to assess the serum retinol concentrations. Retinol absorption was higher in deficient children. In Nepal, the study was conducted in night blind pregnant women who received amaranth leaves, carrots, goat liver, vitamin A fortified rice or retinyl palmitate, for six weeks or all six days. All cases of night blindness showed improvement in all intervention groups except carrot group. When plasma retinol concentrations were considered, it was greatest in liver group followed by vitamin A capsule group.

In another study in Cambodia, school children were given fortified rice with two levels of fortification with vitamin A. both groups consuming rice fortified with vitamin A experienced 50 per cent reduction in vitamin A deficiency (Kuong et al., 2016)

In yet another Indian primary school population, daily receipt of 500 RE did not significantly improve serum retinol concentrations. Whereas consumption of fortified rice with 890µg Re for five improved serum retinol concentrations.

According to WHO, (2007) many countries of the world (~120 countries) have fortified table salt with iodine because iodine is found naturally in very few foods. Salt is traditionally the food vehicle chosen for iodization because it is universally consumed at a relatively consistent intake level; the process of adding iodine to salt is very cheap at less than 5 cents per person per year. Global estimates from the UNICEF indicate that 68% of households have adequate table salt iodine.

Zimmermann, (2009) regards universal salt iodization refers to all salts used within a country, regardless if iodine is in table salt or in salt used by the food industry. Very few countries in the world have achieved universal salt iodization, and often, the food industry does not use iodized salt in food production. Iodine
can also be found in dietary supplements. Universal salt iodization is the most practical strategy to reduce iodine deficiency globally. Correcting iodine deficiency does have some health risks for certain populations in terms of thyroid function and should be considered within the context of each country separately.

West et al., (2012) underline that a change in dietary patterns usually is not enough to ameliorate certain deficiencies such as iodine deficiency given that the root cause is the geographic location in which foods, animals, and seafood are produced. Food-based approaches can include additions or changes to complementary feeding practices when infants start to consume foods other than breast milk or infant formula.

Makwana (2012) says that government of India has issued notification banning the sale of non iodized salt for direct human consumption in the entire country, which was effective from 17th May, 2006 under the Food Adulteration Act. IDD control programme in India is a public health success story. The key factors contributing to this remarkable progress of the IDD control programme in India are effective translation from research to policy, political commitment, involvement of the private sector in production of iodized salt, legislation to ensure iodization of salt and catalytic role played by the troika of academic institutes, civil society and international agencies.

Pandav (2013) expresses that Public Distribution System (PDS) provides an excellent opportunity to reach the unreachable. The key hurdle in achieving USI is ensuring access to quality iodized salt especially for the socio-economically poor strata of the population. This can be overcome by introducing quality iodized salt through PDS. Utilized primarily by the populations below poverty line, providing low-cost quality adequately iodized salt through PDS will ensure that we cover the last one fourth of population which still has limited access to adequately iodized salt. PDS along with Integrated Child Development Services (ICDS) scheme and Mid-day meal (MDM) programme together have huge potential as far as ensuring universal and optimal iodine nutrition to the population is concerned. IDD control programme in India is one of the success stories of public health in the country.
The current 91 per cent household level coverage of iodized salt in India, of which 71 per cent is adequately iodized salt, is a big achievement.

As per the criterion of WHO/UNICEF/ICCIDD for tracking progress towards sustainable elimination of IDD we still have a long way to go.

As per Benoit (2007) Currently, the WHO and UNICEF recommend provision of zinc supplements for 10-14 days along with oral rehydration therapy for acute diarrhoea; however, no routine supplementation recommendations currently exist for the prevention of zinc deficiency.

Mori et al, (2012) found that the effect of zinc on anthropometry, but not linear growth, was also seen in a Peruvian clinical trial in which mothers were supplemented prenatally with zinc; infants born to zinc-supplemented mothers had greater weight gain, higher calf and chest circumference, and more calf muscle area than children born to mothers without zinc supplementation. Zinc supplementation during pregnancy is associated with a significant reduction in preterm births without an effect on infant birth weight.

Radhakrishna (2013) indicates a recent clinical trial in full-term infants in India receiving placebo or 5 mg zinc daily indicated a significantly higher skin fold thickness for infants in the treatment group when compared to the placebo group, without a difference observed in linear growth.

A recent Cochrane review of randomized clinical trials (80 trials with 205,401 participants) in children 6 months to 12 years of age indicates a positive effect for zinc supplementation in reducing all-cause and infectious disease mortality and a small positive impact on linear growth (Mayo-Wilson, 2014).

B_{12} and folate deficiency resulting in anaemia is rare around the world. However, it can occur in both developing and developed countries especially in older people, in those with absorption problems and in vegetarians. Folate fortification of bread products has been made mandatory in Australia and in many other countries, which has reduced this deficiency significantly.
Food Safety Authority of Ireland (2009) report that folic acid supplementation in the preconceptional period unequivocally reduces the occurrence of neural tube defects. For this reason, the governments of both the United States and Canada instituted national fortification programs with folic acid to enhance the diets of reproductive-aged females and neural tube defect rates decreased in both the United States and Canada. Since this time, more than 75 countries have instituted folic acid fortification programs, and the amount of folic acid added varies by country. Several more countries allow folic acid to be added to flour on a voluntary basis, while other countries fortify with iron and other B vitamins, but not with folic acid. Concerns exist about high exposure to folic acid through fortification practices and supplements among nontarget groups (i.e. females not in the reproductive age) like children, males, and the elderly.

‘PATH’ (2012) supports fortification of rice and has experience in scaling up the technology for preparing fortified rice to suit the needs of various developing countries and regions. The area of their experience is in testing, consumer acceptance, micro-nutrient intention, during storage and cooking, consumption of fortified rice and supplementation studies.

The impact of supplementation studies on fortified rice has proved to improve haemoglobin status, total body retinol, serum retinol, vitamin A deficiency, blindness, cognition and physical performance. These studies were conducted in school children in Southeast Asia and South America.