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Iodine and Human Health: Historical Perspectives and Implications for Nepal

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Abstract

Iodised salt has proven to be the most economical and practical way of supplementing dietary iodine in combatting endemic goitre, cretinism and associated negative impacts on psychomotor and mental development associated with subclinical hypothyroidism in children. Iodine deficiency control program in Nepal is a success story that started with the initial iodised oil injection followed by iodised oil capsule supplementation and finally a firmly established salt iodisation program. As demonstrated in several national micronutrient surveys, remote hilly and mountainous regions of Nepal still have some difficulties in accessing iodised salt regularly, possibly due to logistics reasons. In order to ensure uninterrupted supply of dietary iodine, there is a justification to reintroduce some other forms of iodine supplementation in these remote regions. In addition, negative impacts of iodine deficiency on learning ability in children have been well documented in several countries. How can it be reversed by what age and up to what level of severity is open for further research. Given Nepal's diverse ethnicity, culture, food habits and varying climatic conditions at different altitudes, this review paper contributes towards warranting a scientific research on the impact of iodine deficiency in various socio-economic dimension of the society including children's learning ability.

JEL classification: I10, I31
Keywords: Iodine, Goitre, Cretinism, hypothyroidism, learning deficit

1. Introduction

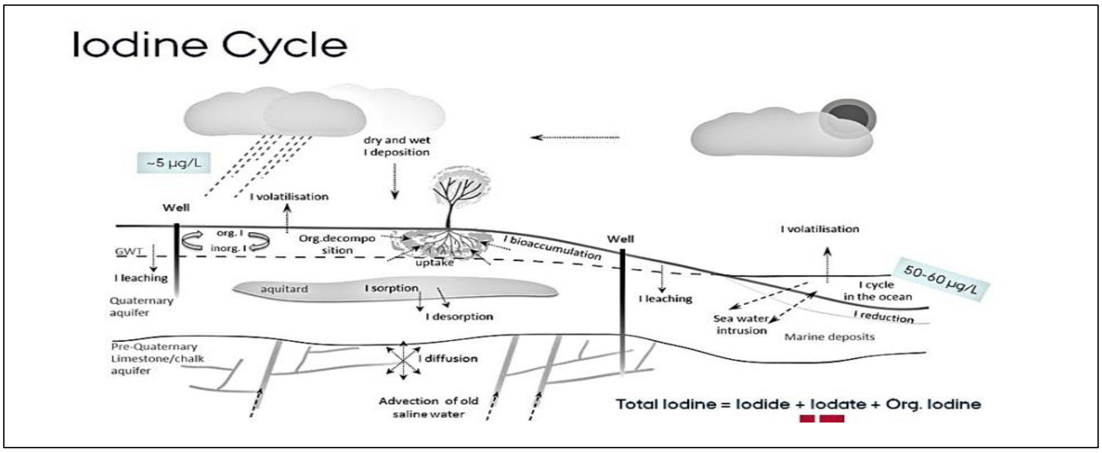
Discussions on how to stay healthy generally focuses on protein, carbohydrates, fat, vitamins, physical exercise, and sometimes iron and vitamin supplements. But there is a range of trace elements that are essential for our brains, muscles, bones, kidneys, skin, cardiovascular and immune systems to function properly (Harvard Medical School, 2016). These include zinc, copper, manganese, selenium, and iodine which our bodies absorb from food (Streit, 2018). Human bodies require these elements in micrograms (µg) or nanograms (ng). Deficiency of these elements has been termed as micronutrient malnutrition or hidden hunger (Messer, 1992). This is distinct from general malnutrition caused by lack of adequate food intake containing proteins and carbohydrates. In 1992, an international conference on nutrition jointly organised by Food and Agriculture Organisation (FAO) and World Health Organisation (WHO) signed-off by 159 governments committed to eliminate hidden hunger (FAO, 1992).

1.1 Natural Cycle of Iodine

Iodine occurs naturally in soil and seawater in the form of iodide (I^-). Seawater contains about 50 µg to 60 µg of iodine per litre. Iodide in seawater reacts with the oxygen in the air, facilitated by sunlight, and is converted to the volatile element, iodine, which evaporates into the air (Fig. 1). Annually some 400 thousand tons of iodine escapes from the sea surface.

Figure 1

Natural life cycle of iodine



Note: Aarhous University, Copenhagen, Denmark

Atmospheric air may contain about 0.7 µg of iodine per cubic meter (Hetzel, 1989). Iodine contained in the air is deposited back to the soil through rain. Rainwater can have iodine in the range of 1.8 µg to 8.5 µg per litre. Soil absorbs this iodine during rain. The iodine contained in surface soil is again leached through rains, surface water, snow, and floods and carried back to the oceans by rivers and tributaries (Cox & Arai, 2014)

As iodine is not uniformly distributed in nature, iodine content of soil depends on geographic location as well as the frequency of rainfall. As a result, iodine contain in food varies considerably depending on where it is grown (Koutras, 1986). Crops grown in different parts of the world and different locations within a country can have different levels of iodine depending on topography. There has not been any scientific study conducted in Nepal to analyse iodine contain in cereals, vegetable and fruits. The only information available in Nepal is on underground water reported at less than 2 µg/l (Hetzel, 1989) while in another study on bottled water showed no trace of iodine at all

(Burlakoti at el., 2020). As a result, crops grown in Nepal could be assumed to be deficient in iodine content.

This review paper intends to highlight the achievements of iodine deficiency disorder control program in Nepal, identify some of the weak links, and offer potential avenues for future scientific works which could contribute to the pool of knowledge on Nepal's continued efforts in mitigating negative impacts of iodine deficiency in Nepal.

2. Iodine in Human Body

2.1 Iodine and the Thyroid Gland

The primary function of the thyroid gland is to store iodine (as thyroglobulin) and to synthesise thyroid hormones - thyroxine (T4) and triiodothyronine (T3), which are released into the bloodstream reaching every cell in the body (Taurog,1986). These two hormones regulate many biochemical functions such as heartbeat, cholesterol levels, protein synthesis, body temperature, enzymatic activities, metabolic activities, and menstrual cycles in women (Sargis, 2016). Two glands in the human brain, namely pituitary gland and hypothalamus, coordinate with the thyroid gland in maintaining balance of T3 and T4 hormones.

2.2 Consequences of Iodine Deficiency

According to World Health Organization (WHO) guidelines an adult human body require about 150 µg of iodine daily (WHO, 2007). When the supply of iodine (in the form of iodate) is reduced below 100 µg per day for extended periods of time, it causes the thyroid gland to overwork in absorbing every atom of iodine available in the blood stream leading to swelling of thyroid gland, which results in goiter (WHO, 2014a). In this condition, the thyroid can be enlarged by a factor of 4 or 5 (Delange, 1985). A population is classified as endemic goitre when 5 percent or more of the adolescent or preadolescent population has grade 1 goitre (visible goitre when neck is raised) (Stanbury, 1987). Besides physical disfigurement and discomfort there are other serious consequences of iodine deficiency, especially in children and pregnant women.

In women during pregnancy, while living in an iodine deficient environment, major neurodevelopmental deficits and growth retardation in the foetus can occur including low birthweight, miscarriage and stillbirth (Bachrach & Burrow, 1985). In infants and children, less severe iodine deficiency can also cause neurodevelopmental deficits as measured by IQ tests (Muzzo et al., 1986). Mild to moderate maternal iodine deficiency has also been associated with an increased risk of attention deficit hyperactivity disorder (ADHD) in children. In adults, mild-to-moderate iodine deficiency can cause impaired mental function and decreased work productivity.

2.2.1 Cretinism

Foetal thyroid glands start to appear during 16th or 17th day of gestation period and by the seventh week it assumes its definitive shape while weighing about 1-2 mg and begins to mature during the third trimester. The foetus starts to produce its own thyroid hormones detectable from about 28 weeks onwards (Fisher, 1985). Consistent lack of iodine during this stage of pregnancy severely impacts this process and results in hypothyroidism and cretinism (Querido et al., 1978). These children also showed lower total intelligence quotient scores compared to children born to women residing in iodine sufficient areas (see below). It is the most serious manifestation of iodine deficiency (Vermiglio et al., 2004).

There are two types of cretinism: first, neurological cretinism which is characterised by a combination of mental retardation, deaf-mutism, squint, spastic diplegia, and deformed stance & gait; and second, myxedematous cretinism, also known as hypothyroid cretinism, which is characterised by a combination of mental retardation (less severe than neurological cretinism), dwarfism, hypothyroidism, and delayed sexual maturation (Delange, 1988). Sometimes an individual can display symptoms of both types of cretinism (Skeaff, 2018). These conditions have severe negative impacts on educability of children with tremendous economic cost (Levine, 1987).

2.2.2 Impacts on Psychomotor Function and Mental Development

Below is the summary of psychomotor development and mental development in children (Guilford, 1971; Cronbach, 1990). These are the issues at stake in population where there is severe deficiency of iodine.

2.2.2.1 Psychomotor development

Psychomotor functions involve a combination of thought process which requires precise motor responses, focused attention on the task, and cognitive problem-solving abilities that require precision. Tests are very age-specific as children's motor development increases progressively as they age. These functions can be measured by simple tasks such as imitative skill, eye-hand coordination, reaction time measurement, tapping skills, etc. The concept behind these tests is to measure information processing time/speed, eye-hand coordination, dexterity, perseverance and accuracy.

2.2.3 Mental development

Mental development of children is a cumulative gain in perfections in verbal skills, visual memory, and other cognitive functions. These functions include *fluency* - assessing long term memory, explicit memory, recollection and recognition skills; *exclusion* - measuring reasoning and differentiation skill involving relations, visual and figural units; *quantitative skill* – measuring figural relationships, physical properties, and concept development; *verbal meaning* – measuring vocabulary skills, classification, comprehension, appreciation, and semantic units (thought process); *visual memory* – measuring the relationship between perceptual processing and the encoding, storage, and retrieval of the stored neural representations (decoding information); *closure* - figural unit, perceptual speed, and ability for reconstruction.

In areas with severe endemic goitre an abnormally high number of individuals exhibiting irreversible anomalies of intellectual and physical development were noted. A number of scientific studies reported the presence of various levels of mental retardation in areas with endemic cretinism such as Papua New Guinea, Ecuador, Java in Indonesia, and Ubangi in Zaire (DeLange, 1986).

A combination of these two sets of tests – psychomotor and mental development – assesses a child's intellectual ability. Prenatal and early postnatal malnutrition have been known to show negative impacts on intellectual quotient. It has been demonstrated that iodine supplementation during pregnancy in high prevalence endemic goitre improves IQ of children compared to children in non-supplemented areas indicating clear role of thyroid hormones on psychomotor and mental development of children (Muzzo et al., 1986).

One of the earliest studies on the long-term impact of correction of iodine deficiency on psychomotor and intellectual development was conducted in Ecuador in the 1960s by Fierro-Benitez and colleagues. This case-control longitudinal study reported improvement in goitre prevalence and improved school performance (reading, writing, mathematics, natural science, and drop in grade repetition) by children in treated villages compared to children in untreated villages (Fierro-Benitez et al., 1986). A meta-analysis of 21 such studies conducted in six countries reported an IQ improvement of 13.5 in schoolchildren in iodine corrected populations (Bleichrodt & Born, 1993).

3. Prophylaxis and treatment with iodine supplementation

There are three methods of iodine supplementation. First method used was iodisation of salt. Switzerland was the first country to introduce iodised salt in 1922 (Burgi & Supersaxo, 1990). This was followed by iodisation of table salt in Guatemala, Colombia, Finland, and China (Mannar, 1987). Now, table salt fortified with potassium iodate has become a universal phenomenon.

The second option is to use iodised oil given intramuscularly to treat and prevent goitre and cretinism. During the early years of 1960s, Papua New in Guinea with high prevalence of goiter was of considerable interest to many researchers. Clarke et al. (1960) was the first to study the impact of iodised oil injection to the general population by injecting 2ml of poppy seed based iodised oil. This study was repeated in 1963 by injecting 4 ml of iodised oil (Buttfield & Hetzel, 1969). There was yet in another study conducted by in Papua New Guinea by Pharoah in 1966 in a case-control study involving more than 16,000 subjects in 27 villages with intermittent follow up for five years (Pharoah et al., 1972). This experiment was successfully repeated in Ecuador (Ramirez et al., 1972), Sudan (Eltom et al., 1985), and several other countries with iodine deficiency problems. The researchers concluded that intramuscularly administered iodised oil is good for as long as four years (Pharoah et al., 1972).

The third method of iodine supplementation is through oral administration which has been tried with positive outcome in preventing and treating endemic goiter such as in Zaire (Tonglet et al., 1992), Tanzania (Peterson et al., 2000), Sudan (Eltom et al., 1985), Pakistan (Anees et al., 2015), Nepal (Ministry of Health, 1998), etc.

4. Iodine deficiency in the Nepalese context

Presence of goitre in Nepal was sporadically reported by various Everest climbers during the early twentieth century. The very first goitre prevalence survey in Nepal was conducted in 1965 which reported a total goitre rate of 55 per cent in children above the age of 13 years (Ministry of Health, 1967). This was later confirmed by the first known scientific study conducted by a team of New Zealand scientists in 1966 in the Everest region (Ibbertson et al., 1972). The authors reported the presence of visible goitres among 63 per cent of examined population with a further 30 per cent with palpable goitres. The authors also reported high prevalence of deafness, deaf-mutism, and cretins in all villages surveyed in the Khumbu region, eastern Nepal. The findings reported varying degrees of deafness, speech defects, and intellectual and motor disorders among the populations examined.

The study team led by Ibbertson et al. (1972) injected the local population with iodised oil in 1966 and were followed up in 1972. The authors reported decline in visible and palpable goitres among the population with just one cretin being born in the region, which was among non-treated population.

The Nepal Micro Nutrient Status Survey report of 1998 listed a number of surveys conducted in different years as listed in Table 1. These surveys as presented in the report did not provide details of the locations covered by the surveys, population covered or the age breakdown of the survey population. The results of all these surveys, however, unmistakably demonstrated presence of goiter and its associated aliments as serious problem in Nepal. In another survey in 1980 in Dolakha district, north-east of Kathmandu, a researcher reported 107 cretins in a population of 2456 (Achard, 1987). It indicates serious deficiency of dietary iodine in the population. It is likely that majority of people living along the northern mountainous belt in similar latitude as those living in Dolakha district suffer from iodine deficiency.

Table 1

Prevalence of goitre in Nepal by age groups and year of survey (Ministry of Health, 1998)

Survey year	Age group	Scope of survey	Total goitre rate
1965	>13 years	National	55.0
1976/77	All ages	Trishuli & Langtang	55.3
1979/82	All ages	14 districts	57.6
1985/86	All ages	15 districts	39.7
	School age	Not mentioned	44.2
1992	School age	2 districts	32.0

Note: Ministry of Health, 1998. Nepal Micro Nutrient Status Survey, His Majesty's Government of Nepal

The survey conducted by the government of Nepal in 1965 and another survey in 1966, which included intervention by Ibbertson et al. (1972), were instrumental in establishing Goiter Control Program in 1973 in Nepal, which was implemented by the Ministry of Commerce and Supplies. The primary aim of this project was to import iodised salt from India to provide iodine supplement to the entire population. A second project, Goitre & Cretinism Control Project, was established under the Ministry of Health and Population in 1979 with UNICEF assistance. This project focused on iodised oil injection program in 40 mountainous districts. The iodised oil injection was administered every five years till 1993 to all women and children. From 1993 onwards, iodised oil injection was replaced by iodised oral capsules distributed by Village Health Workers annually, which lasted till 2002. The iodised oil capsules distribution program covered children up to the age of 15 and women till the age of 45 years in 15 hilly and mountainous districts. Distribution of iodised oil capsules was phased out as availability of iodised salt throughout the country became a reality with improvements in road transport networks (Ministry of Health, 2012).

It is generally believed that there are observer variations (bias) in estimating palpable goiter which impacts in estimation of total goiter rate. According to WHO, for epidemiological purposes urinary iodine concentration in school-aged children is considered as a good indicator of iodine status for the general population. The WHO recommends 100 ug/l of iodine in urine as the median cut-off point to determine iodine status. Table 2 below summarises the criteria for classification of iodine nutrition based on urinary iodine concentrations in school-aged children for the general population and for pregnant women (WHO, 2013). It is considered to be the most practical biochemical marker of iodine nutrition as opposed to total goiter rate.

Table 2

Epidemiological criteria for classification of iodine nutrition based on urinary iodine concentration in school-age children (World Health Organisation, 2013)

Population groups		**Iodine indicator**	
General population	Pregnant women	Iodine intake	Iodine status
Urinary iodine concentration in ug/l			
≤20		Insufficient	Severe iodine deficient
20-49		Insufficient	Moderate iodine deficient
50-99	≤150	Insufficient	Mild iodine deficient
100-199	150-249	Adequate	Optimal
200-299	250-499	More than adequate	
≥ 300	≥ 500	Excessive	Risk of adverse effect

Note: World Health Organisation, 2013. Urinary iodine concentrations for determining iodine status in populations.

The 1998 Nepal micronutrient status survey reported 56 per cent of the adult women with urinary iodine level above the cut-off point of 100 ug/l (Table 3). In other words, 44 per cent of the population have below the required level of iodine nutrition. Similarly, among pregnant women too, only 55.6 per cent have urinary iodine concentration above the recommended cut-off point. The survey also indicated an urban rural bias with population in urban areas with 78 per cent of population having above the cut-off point of urinary iodine secretion. In Terai region where transportation and access to household commodities are considered easier than hilly and mountainous regions, iodine nutrition status was found lower as indicated by urinary iodine excretion (Ministry of Health, 1998).

Table 3

Urinary Iodine Status among women population by different characteristics (Ministry of Health, 1998)

Ecological zone	Sample size	Median ug/l in sample	Per cent of women with different severity of iodine deficiency			WHO median cut-off point	
			≤20 severe	20-49 mild	50-99 moderate	<100 ug/l	>100 ug/l
Terai	613	86.0	4.6	17.8	35.5	57.8	42.2
Hills	598	142.7	1.7	9.6	20.7	32.0	68.0
Mountains	102	168.6	2.0	8.2	19.4	29.6	70.4
Pregnancy status							
Pregnant	132	134.0	3.1	13.4	27.9	44.4	55.6
Nonpregnant	1169	112.0	0.8	14.0	27.1	41.9	58.1
Residency							
Urban	193	205.0	2.1	7.8	12.4	22.3	77.7
Rural	1120	105.0	3.2	14.3	30.2	47.7	52.3
National (N)	1313	114.1	3.1	13.3	27.5	43.6	56.1

Note: Ministry of Health, 1998. Nepal Micro-nutrient status survey, His Majesty's Government of Nepal

There are few other studies on iodine deficiency disorders based on urinary iodine excretions. Baral et al. (1999) collected 7,797 samples from children in all 75 districts in Nepal in 1998. In another study Gelal et al. (2009) collected 1,094 urine samples in 2006 representing all geographic and administrative regions. The findings of these two studies are presented in Table 4. As can be seen in the table, there is decrease in severe and moderate form of iodine deficiency disorder as noted between the two studies, from 2006 to 1998 in Terai and hilly regions and nationally as well; however, the mild form of iodine deficiency appear to be on the rise across all ecological zones.

Table 4

Per cent prevalence of iodine deficiency based on urinary iodine excretion by severity and ecological zone by survey period (Baral et al., 1999; Gelal et al., 2009)

Iodine nutrition status	Ecological/geographic regions						National	
	Terai		Hilly		Mountainous			
	Urinary iodine concentrations in ug/l							
	1999[1]	2009[2]	1999[1]	2009[2]	1999[1]	2009[2]	1999[1]	2009[2]
Severe	7.8	0.4	4.3	1.4	3.1	5.9	5.4	1.8
Moderate	3.0	2.2	2.4	2.5	2.6	4.4	2.7	2.7
Mild	8.1	15.5	4.3	14.5	3.2	28.1	5.5	17.5
Optimal	NA	29.7	NA	30.7	NA	37.4	NA	31.5
>Adequate	NA	26.9	NA	26.6	NA	15.3	NA	24.8
Excessive	NA	25.3	NA	24.2	NA	7.9	NA	21.7

Note: NA – Not available; [1] Data collected in 1998; [2] Data collected in 2006

5. Government policy in controlling Iodine Deficiency Disorder (IDD)

The government of Nepal decided universal salt iodisation as the long-term strategy for control of IDD in Nepal. Nepal's trade with India is based on its first trade and transit treaty signed with British India in 1816, popularly known as the *Sugauli treaty* (Analytica2Action, 1) which was subsequently amended in 1950 (Analytica2Action, 2) after Indian independence. This treaty governs all import, export, and transit arrangements between Nepal and India. The government assigned Salt Trading Corporation, established in 1963, as the first public-private partnership venture with the responsibility of importing iodised salt for human consumption (Salt Trading Corporation, 2021). Although iodised salt importation started in 1973, the level of iodine content in the salt remained erratic. In 1998 the Government of Nepal reinvigorated its policy of universal distribution and marketing of iodised salt throughout the country by establishing five salt iodisation plants at India-Nepal border entry point (Dhangadi, Nepalgunj, Bhairahawa, Birgunj and Biratnagar) from where all salt enters Nepal. The government also stipulated requirements for iodination of salt with 50 ppm of iodine at the production level with the expectation of 30 ppm at the retail outlets and 15 ppm at the consumption point.

Salt is marketed in 1kg bags with inside plastic lining and also sold in lose form so that people can buy smaller quantities as needed. In addition, rock salt imported from Tibet is also available in western mountainous region (Ministry of Health, 1998). Operation of these salt iodation program is managed by Salt Trading Corporation.

Further, the Government of Nepal drafted national legislation prohibiting the import, production, marketing, and distribution of non-iodised salt in 1998 (Law Commission, 1998). According to Article 23, any offender could be punished with a financial penalty and/or a one-year imprisonment). However, this act has not yet been gazetted, hence not operationalised (Paudyal et al., 2020).

As reported in Nepal multiple indicator cluster survey of 2014, Nepal has made substantial progress in making available iodised salt throughout the country with 81.5 per cent of the population having iodised salt with 15+ ppm iodine in the salt at the household level (consumption point) (Central Bureau of Statistics, 2015). The survey, however, reported variations in the consumption of iodised salt with respect to geo-economic indicators (Table 5). For example, people in urban areas and people belonging to highest wealth quintile consume adequately iodised salt, 96.4 per cent and 98 per cent, respectively, for 15+ ppm iodine while 22.2 per cent and 36.5 per cent of rural population and population in lowest quintile, respectively, consume salt with < 15 ppm iodine.

Table 5

Per cent of households with adequate and inadequate concentration of iodine in table salt by various social indicators (Central Bureau of Statistics, 2015)

Per cent of households consuming salt with		
	15+ ppm iodine	<15 ppm iodine
Urban	96.4	3.6
Rural	77.8	22.2
Highland	82.6	17.4
Tarai	80.3	19.7
Richest	98.0	2.0
Poorest	63.5	36.5
National	81.5	18.5
	N=12,379	

Note: Nepal multiple indicator cluster survey, 2014 Ministry of Health and UNICEF (Central Bureau of Statistics, 2015)

A study conducted in 2013 in four districts in Eastern Nepal - Sunsari, Dhanakuta, Sankhuwasbha and Tehrathum – also showed variation in iodine content in salt at the household level analysed by two methods - rapid test kit method and iodometric titration method - with 24.5 per cent and 17.4 per cent of salts with below 15 ppm of iodine, respectively, (Nepal et al., 2013). The results show substantial difference between the two methods in all districts (Table 6).

Table 6

Per cent of households with iodine content in table salt by districts and iodine analysis methods (Nepal et al., 2013).

Level of iodine content	**Survey districts**				
Rapid test kit	Sunsari	Dhankuta	Sankhuwasbha	Tehrathum	All total
<15 ppm	39 (20%)	17 (8.7%)	89 (66%)	28 (15%)	173 (24.5%)
>15 ppm	152 (80%)	178 (91.3%)	46 (34%)	158 (85%)	534 (75.5%)
Titration method					
<15 ppm	46 (24%)	35 (18%)	32 (23.7%)	10 (5.4%)	123 (17.4%)
>15 ppm	145 (76%)	160 (82%)	103 (76.3%)	176 (94.6%)	584 (82.6)

Another national survey conducted in 2016 showed slight improvement in iodine content in edible salt with 9 per cent having less than 15ppm of iodine including 4 per cent of salt with no iodine at all (Ministry of Health & Population, 2018). Households with inadequate levels of iodine were mostly in mid- and-far western regions, similar to the findings of 2014 survey.

6. Discussion

6.1 *Impact of using of iodised salt in Nepal*

National surveys conducted in various years showed sustained improvements in consumption of iodised salt which improved iodine intake as demonstrated by urinary iodine excretion data among the sample populations studied. These findings have also been supported by various surveys conducted by individual authors. The lack of iodine or inadequate amount of iodine in salts collected during various surveys and urinary iodine below the cut-off point could be due to consumption of salt which lost its iodine during transportation and storage. A proper network for regular monitoring of iodination, transportation and storage to track quality, distribution, and marketing of iodised salt is still essential to maintain the quality of salt with required level of iodine. Overall, salt iodination programin Nepal is considered a success story.

Based on several studies referred above, some 10 to 20 per cent of people in the Far-western Nepal seem to be most at risk against iodine deficiency disorder due to the lack of adequately iodised salt at the household level (based on iodine contained in salt as well as urinary iodine excretion data). Other social factors which indicate vulnerability towards iodine deficiency include the level of poverty and being rural resident.

The issue is not salt consumption as such. The fundamental issue is its negative impact on children's learning ability which makes it extremely important. The government should make necessary effort to ensure that everyone has access to adequately iodised salt at all times. It may be necessary to give especial emphasis to Far-western region of Nepal and to the rural poor in Terai region.

Recently, a concern has been raised regarding excessive iodine intake demonstrated by median urinary iodine concentration (mUIC) of 314 µg/L among school children (MEOR, 2020). It led to a question if there is a need to recalibrate current level of iodination at the factory level. The WHO expert panel considers mUIC above 300 µg/L to be excessive (WHO, 2014b). The excessive level of urinary iodine could be due to over consumption of prepacked street foods which is available everywhere. A serious analysis is required to review the distribution and availability of street foods and prepacked snacks before taking a decision to recalibrate iodine concentration in the salt iodisation process, as it will affect all households in the country. Zimmermann (2008) suggests that there may be 'transiently' increase in the incidence of thyroid disorders due to iodine excesses but overall the relatively small risks of iodine excess are far outweighed by the substantial risks of iodine deficiency.

6.2 Policy implications for Nepal

The problem of iodine deficiency has been successfully mitigated by the government of Nepal with effective implementation of iodised oil injection followed by iodised oil capsules distribution program, eventually culminating in a successful national salt iodination program. The focus should now be in closing the gap in iodised salt consumption in remote regions especially in Far-western Nepal where 10 to 20 per cent of households still consume salt with no iodine or with inadequate iodine content.

Annual supplementation with iodised oil capsules may still be an option in those remote regions while availability of iodised salt become universal on regular basis. Médecins Sans Frontières (MSF), an International Non-governmental Organisation has a policy of annual distribution of iodised oil capsules - 190 mg to 570 mg to children depending on age and 380 mg to pregnant women residing in known iodine deficient areas where MSF operates (Medecins Sans Frontiers Doctors without Borders, MSF, 2021). There is a strong justification for this course of intervention as lack of iodine in children in early years has negative impacts on educability and decreased work labour productivity in adults.

6.3 Possible future course of action in Nepalese context

The following could be considered as concrete steps to strengthen the iodine deficiency disorder control program in Nepal:

- Since 1998 the Government of Nepal designated February as 'Iodine month' to raise awareness on the importance of iodine nutrition by promoting iodised salt. This campaign should focus on refined salt and discouraging the use of crystalline salt and Tibetan salt for human consumption. The campaign may require an added focus in Far-western Nepal.
- Consider gradual phasing out of importing large crystalline salt. If the price difference between fine and large crystalline salt is an issue the price difference could be absorbed by the government so that everyone will only buy refined iodised salt.
- The government should reconsider annual distribution of iodised oil capsules to children and women of reproductive age, especially in remote areas where consumption of iodised salt remains a problem such as in Far-western region of Nepal.
- There is broad agreement among the scientific community on the benefits of iodine supplements orally or through injectables; however, there is still no agreement on lower and upper limits on concentration of iodine in the oral capsules and for intramuscular use. In various trials, the iodine content ranged from as low as 118 mg in Zaire to 960 mg in Burma for oral use. Iodised oil injection is usually limited at 1 ml or 2 ml in most cases, except in New Guinea where a study used up to 4 ml (1.6 gm of elemental iodine). Likewise, iodised oil preparations are made with walnut oil, poppy seed oil, soybean oil, or plant oils but there is no scientifically proven data as to which oil is the best vehicle when it comes to absorption of iodine in the body. In that regard, (bring below paragraph here)

  Nepal could initiate a research on iodine oil capsules based on different preparations in remote areas where iodine deficiency is still prevalent. It may help determine which oil in which concentration is best suited for Nepal.
- There is a lack of studies on iodine contents in food crops grown in Nepal. Given the topography of Nepal, crops and vegetable grown in the country will most likely be iodine deficient thus bioavailability of iodine will remain very low. Nepal's diverse ethnic population have adapted to a wide ecological zone with diverse cultural and food habits. Nepal could conduct a scientific study on the impact of iodised oil supplementation on psychomotor and mental development of children and its impacts on school performance in different ecological zones of Tarai, Hills and Mountainous regions. The test instruments for such a study can be

adapted from a number of psychological and cognitive tests such as Stanford-Binet Intelligence Scale, Leiter International Performance Scale, Gesell Developmental Schedules, BenderGestalt Test, Raven Colored Progressive Matrices, Goddard Test for Psychomotor Development, Brunet-Lezine Scale, etc. Various components from these modules have been adapted to eliminate cultural biases in studies in Ecuador (Fierro-Benitez et al., 1986), in Spain (Bleichrodt et al., 1986) in Malawi (Shrestha, 1994) and many other countries to assess impact of iodine supplementation on psychomotor and mental development of children.

7. Conclusion

The Government of Nepal has done a creditable job in controlling the problem of iodine deficiency disorder in Nepal. An initial use of iodised oil injection followed by iodised oil capsule distribution to the targeted population in hilly and mountainous region was proved to be a good strategy. The salt iodination program now has taken a firm root. There are, however, 10 to 20 per cent of population groups in Far-western region of country and some in Terai region, where consumption of iodised salt remains low as found in urinary iodine assessments. It would be advisable to reinstate iodised oil capsule supplementation to children and women residing in far western region and in rural Terai.

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