Review Article

Need for neonatal screening program in India: A national priority

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ABSTRACT

In India, out of 342 districts surveyed, 286 have been identified as endemic to iodine deficiency (ID). Research studies conducted in school age children (SAC), Adolescent girls, Pregnant Mothers (PMs) and Neonates have documented poor iodine nutritional status. As observed by total goiter rate of more than 5% and median urinary iodine concentration level of <100 µg/l in SAC and <150 µg/l in PMs as prescribed cutoff of World Health Organization. And higher thyroid stimulating hormone levels among neonates. ID leads to compromised mental development and hence which remain hidden and not visible to family, program managers and administrator. The present review describes the current status of ID in different parts of the country. With a view to strongly recommend the implementation of Neonatal screening program for ID so that the optimal mental development of children can be achieved.

Key words: Iodine deficiency, neonatal hypothyroidism, neonates

Introduction

Iodine deficiency (ID) is the single most important and preventable cause of mental retardation worldwide.[1] ID in fetus results in miscarriages, stillbirths, brain disorders, retarded psychomotor development, speech and hearing impairments.[2-5] People living in areas affected by severe ID may have an intelligence quotient (IQ) of up to 13.5 points below that of those from areas where there is no ID.[6] ID Disorders (IDD) have been found to be associated with at least six of the 8 millennium development goals.[7,8] ID directly affects human resource development which in-turn greatly affects the human productivity and country's development at large.

Methodology

In order to identify relevant studies for this review, an initial search was conducted using the U.S. National Library of Medicine's PubMed website (http://www.ncbi.nlm.nih.gov/PubMed) using the keywords ID, school age children (SAC), pregnant mothers (PMs), adolescent girls, neonates, neonatal hypothyroidism (NH) and India. The titles and abstracts of the articles identified were reviewed, and full copies of the most relevant articles were obtained. Studies on ID in relation to SAC, PMs and neonates and studies on NH were also reviewed. Additional articles were identified in several different ways: From the list of citations in relevant publications, by searching the table of contents of journals that contained relevant articles but were not indexed in PubMed, and from internet based searches other than PubMed, using the keywords "ID, NH and India.

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Results

Magnitude of iodine deficiency

Iodine deficiency disorders constitute a major nutrition deficiency disorder in India. It has been estimated that 200 million people in India are exposed to the risk of ID and more than 71 million suffer from goiter and other IDDs. A survey conducted by the Central and State Health Directorates, Indian Council of Medical Research and Medical Colleges has demonstrated that not even a single state is free from the problem of IDD. Out of 582 districts, district-level surveys have been conducted in 325

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districts. It has revealed that IDD is a major public health problem in 263 districts, that is, prevalence of IDD was above 10% in the population. The status of urinary iodine concentration (UIC) levels in different regions of India has been extensively assessed by district-level surveys in recent years. More than 86% of districts had median UIC levels of >100 μg/l indicating success of National IDD control program.[9]

Iodine status amongst school age children

School age children are the preferred group as they are easily accessible, vulnerable to ID and respond to salt iodization program. According to World Health Organization (WHO)/United Nations Children's Fund/International Council for the Control of Iodine Deficiency Disorders, if >5% SAC (6–12 years) are suffering from goiter, region should be classified as endemic to ID.[10]

Table 1 depicts the UIC levels amongst school age children in different parts of the country. Table 2 depicts the iodine content of salt samples collected at beneficiary level in selected districts of India.

Iodine status amongst pregnant mothers

Pregnant mothers are most vulnerable to ID because their requirement is the highest. The recommended daily Allowance of iodine of PMs is higher (250 μg/d) as compared to normal adult (150 μg/d). During pregnancy, recommended dietary allowance of iodine is increased by 50% due to (i) physiological increase in maternal and fetal thyroid hormone production and (ii) increase in renal iodine losses.[10] Consequently, if PM is iodine deficient there is decrease synthesis of thyroxin by fetal thyroid that leads to compromised mental and physical development of the fetus. According to WHO, the median UIC level of <150 μg/l amongst PMs indicates ID in the community.[10] Pregnant women with normal thyroid stimulating hormone (TSH) levels often have low free T4 levels, even in areas in which iodine intake is sufficient within the general population. This condition is termed as hypothyroxinemia. Recent findings suggest that the hypothyroxinemia can negatively affect child health outcomes, including neonatal behavior and infant cognitive functioning.[11,12]

Studies conducted in various regions of the world with varying iodine status have assessed the impact of maternal iodine status on that of neonates and on thyroid function and neuropsychiatric development of neonates.[13,14] A study conducted on overt and subclinical thyroid dysfunction among Indian pregnant women and its effect on maternal and fetal outcome reported significant adverse effects on maternal and fetal outcome. Thus, emphasizing the importance of routine antenatal thyroid screening. There is limited data on the prevalence of ID among the PMs in India.

Table 1 depicts the UIC levels among PMs in different parts of the country. Table 2 depicts the iodine content of salt samples Collected at Beneficiary Level in Selected Districts of India.

Iodine status amongst newborns

Neonatal hypothyroidism is one of the most common preventable causes of mental retardation in children. The complications of NH such as intellectual impairment and neurodevelopment delay present later in life when it is too late to be treated or reversed. Timely treatment is very important to effect adequate neurocognitive development during the critical first 3 years of life. The earlier the treatment is started, the higher the IQ levels are achieved later in life.

The neonatal brain is only a third of the size of the adult's brain, if ID and neonatal thyroid failure continue for about 3 months, this condition can lead to irreversible brain damage. Based on scientific data available, it is estimated that about 10% or more of newborns in severe goiter endemic areas are at risk of NH and resultant compromised physical and mental development.[90] Infants born to mothers, who have thyroxin concentration below the 10^{th} percentile before the 13th week of gestation, have impaired neuropsychological development and maturation of the central nervous system.[91] The recognized role of thyroid hormones in brain development and the irreparable nature of brain damage caused by untreated hypothyroidism early in life.[92]

The incidence of NH observed strikingly different in the endemic and non-endemic areas. It has been observed that the incidence (4% or more) of NH in endemic goitrous areas of Gonda (UP) is 100–300 fold higher than reported from developed countries with no environmental ID (EID) or goiter.[93,94]

In areas with a high incidence of NH and ID, a significant proportion of the population may have varying degrees of mental sub-normality and sensory neural hearing loss. These consequences are regarded as the hallmark of ID related brain damage.

Indian scenario

Neonatal hypothyroidism is due to inadequate thyroid hormone production in newborns and its exact incidence in India is unknown. Universal neonatal screening (NS) is still not practiced in developing countries. There is a lack of data on the NS for hypothyroidism from India. Earlier

Table 1: Urinary iodine excretion levels in selected districts of India

State	Name of the district	Year	Number of urine samples	Median (µg/l)	Urinary iodine excretion levels (µg/l)				Reference
					<20.0	20.0-49.9	50.0-99.9	≥100.0	
Assam	Dibrugarh	2001	2040	115.0	NA	NA	NA	NA	[8]
	Nagaon	2001	1836	115.0	NA	NA	NA	NA	[8]
	Dibrugarh	2003	210	167.0	12 (5.7)	13 (6.2)	26 (12.4)	159 (75.7)	[15]
	Dubri	2003	210	205.0	4 (1.9)	10 (4.8)	30 (14.3)	166 (79.0)	[15]
	Changlong	2003	193	110.0	4 (2.1)	31 (16.1)	47 (24.4)	111 (57.4)	[15]
Andaman and Nicobar	Andaman and Nicobar	2004	154	200.0	0 (0.0)	5 (3.3)	9 (5.8)	140 (90.9)	[16]
Andhra Pradesh	Mehboobnagar	2001	1748	150.0	NA	NA	NA	NA	[8]
	Adilabad	2003	210	140.0	6 (2.9)	23 (11.0)	42 (20.0)	139 (66.1)	[15]
	East Godavari	2003	210	118.0	9 (4.3)	28 (13.3)	51 (24.3)	58.1	[15]
	Vijayanagram	2004	21	>200.0	0 (0.0)	0 (0.0)	1 (4.8)	20 (95.2)	[17]
	Srikakulam	2004	33	>200.0	0 (0.0)	0 (0.0)	2 (6.1)	31 (93.9)	[17]
	East Godavari district	2004	102	>200.0	0 (0.0)	0 (0.0)	0 (0.0)	102 (100)	[17]
	West Godavari district	2004	70	>200.0	0 (0.0)	0 (0.0)	1 (1.4)	69 (98.6)	[17]
	Guntur	2004	120	>200.0	0 (0.0)	0 (0.0)	2 (1.7)	118 (98.3)	[17]
	Prakasam	2004	102	150.0	1 (1.0)	3 (2.9)	14 (13.7)	84 (82.4)	[17]
	Warangal	2004	100	>200.0	1 (1.0)	0 (0.0)	7 (7.0)	92 (92.0)	[17]
	Adilabad	2004	101	125.0	0 (0.0)	8 (7.9)	25 (24.8)	68 (67.3)	[17]
	Kurnool	2004	103	130.0	0 (0.0)	4 (3.9)	18 (17.5)	81 (78.6)	[17]
	Mehboobnagar	2004	100	150.0	2 (2.0)	5 (5.0)	19 (19.0)	74 (74.0)	[17]
	Chittor	2004	100	100.0	0 (0.0)	4 (4.0)	45 (45.0)	51 (51.0)	[17]
	Nellore	2004	93	>200.0	0 (0.0)	0 (0.0)	0 (0.0)	93 (100)	[17]
	Krishna	2004	96	>200.0	0 (0.0)	0 (0.0)	1 (1.0)	95 (99.0)	[17]
	Khammam	2004	100	200.0	0 (0.0)	0 (0.0)	3 (3.0)	97 (97.0)	[17]
	Hyderabad	2004	174	150.0	8 (4.6)	22 (12.6)	31 (17.8)	113 (64.9)	[17]
	Nizamabad	2004	200	150.0	18 (9.0)	11 (5.5)	25 (12.5)	146 (73.0)	[17]
	Rangareddy	2004	107	65.0	1 (0.9)	23 (21.5)	48 (44.9)	35 (32.7)	[17]
	Anatpur	2004	98	100.0	1 (1.0)	7 (7.1)	38 (38.8)	52 (53.1)	[17]
	Cuddapah	2004	97	90.0	9 (9.3)	15 (15.5)	28 (28.9)	45 (46.4)	[17]
	Vishakapatnam	2004	35	>200.0	0 (0.0)	0 (0.0)	1 (2.9)	34 (97.1)	[17]
Bihar	West Champaran	1997	123	100.0	20 (16.3)	15 (12.2)	25 (20.3)	63 (51.2)	[18]
	East Champaran	1997	138	100.0	12 (8.7)	20 (14.5)	36 (26.1)	70 (50.7)	[18]
	Sahibganj	1998	136	90.0	2 (1.5)	43 (31.6)	29 (21.3)	62 (45.6)	[19]
	Palamu	1998	159	160.0	1 (0.6)	7 (4.4)	17 (10.7)	134 (84.3)	[19]
	Gaya	2001	1802	90.0	NA	NA	NA	NA	[8]
	Patna	2001	1671	109.0	NA	NA	NA	NA	[8]
	West Champaran	2003	206	110.0	10 (4.9)	13 (6.3)	67 (32.5)	116 (56.3)	[15]
	Palamu	2003	209	120.0	16 (7.7)	32 (15.3)	43 (20.6)	118 (56.5)	[15]
	All districts	2006	1169	85.6	NA	368 (31.5)	NA	NA	[20]
Chattisgarh	Shahdol	2003	205	50.0	61 (29.8)	39 (19.0)	43 (21.0)	62 (30.2)	[15]
	Sarguja	2003	210	113.0	31 (14.8)	11 (5.2)	46 (21.9)	122 (58.1)	[15]
Delhi	Delhi	1996	1652	170.0	35 (2.1)	138 (8.4)	291 (17.6)	1188 (71.9)	[21]
	Delhi	2004	680	150.0	17 (2.5)	35 (5.1)	104 (15.3)	524 (77.1)	[22]
	Delhi	2005	749	150.0	17 (2.3)	48 (6.4)	109 (14.6)	575 (76.8)	[23]
	Delhi	2010	1230	198.4	24 (1.9)	53 (4.3)	117 (9.5)	1036 (84.2)	[24]
	Delhi	2010	997	352.8	NA	NA	NA	NA	[25]
	Delhi	2011	1230	198.4	22 (1.9)	53 (4.3)	117 (9.5)	1036 (84.2)	[66]
	Delhi	2013	1393	200.0	NA	NA	NA	NA	[67]
Gujarat	Surat	2003	209	90.0	31 (15.0)	27 (13.0)	56 (26.6)	95 (45.4)	[15]
	Valsad	2003	209	70.0	51 (24.6)	29 (13.8)	52 (25.1)	76 (36.5)	[15]
	Panchmahal	2007	15900	70.0	NA	NA	NA	NA	[26]
	Saurashtra	2010	2010	420.0	110 (5.4)	NA	NA	NA	[27]
	Kutch	2011	420	110.0	NA	NA	NA	NA	[68]
	Bharuch	2012	420	110.0	21 (5.0)	55 (13.1)	107 (25.5)	237 (56.4)	[69]
	Vadodara	2014	256	297.1	NA	NA	NA	NA	[70]
Haryana	Sonepat	2003	207	150.0	5 (2.4)	13 (6.3)	39 (18.8)	150 (72.5)	[15]
	Sonipat	2009	152	200.0	1 (0.7)	3 (2.0)	8 (5.3)	140 (92.1)	[28]
	Panipat	2009	190	150.0	1 (0.5)	5 (2.6)	28 (14.7)	156 (82.1)	[28]
	Karnal	2009	152	200.0	0 (0.0)	0 (0.0)	1 (0.7)	151 (99.3)	[28]
	Yamuna nagar	2009	152	210.0	0 (0.0)	0 (0.0)	3 (2.0)	149 (98.0)	[28]
	Kurukshetra	2009	152	200.0	0 (0.0)	2 (1.3)	7 (4.6)	143 (94.1)	[28]
	Ambala	2009	152	182.0	0 (0.0)	1 (0.7)	5 (3.3)	146 (96.1)	[28]

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Table 1: *Contd...*

State	Name of the district	Year	Number of urine samples	Median (µg/l)	Urinary iodine excretion levels (µg/l)				Reference
					<20.0	20.0-49.9	50.0-99.9	≥100.0	
	Kaithal	2009	168	200.0	0 (0.0)	5 (3.0)	12 (7.1)	151 (89.9)	[28]
	Jind	2009	152	210.0	0 (0.0)	0 (0.0)	7 (4.6)	145 (95.4)	[28]
	Sirsa	2009	202	150.0	0 (0.0)	5 (2.5)	46 (22.8)	151 (74.8)	[28]
	Fatehabad	2009	152	200.0	0 (0.0)	0 (0.0)	14 (9.2)	138 (90.8)	[28]
	Hissar	2009	152	191.0	1 (0.7)	1 (0.7)	17 (11.2)	133 (87.5)	[28]
	Bhiwani	2009	159	200.0	0 (0.0)	1 (0.6)	11 (6.9)	147 (92.5)	[28]
	Mahendragadh	2009	152	210.0	0 (0.0)	0 (0.0)	1 (0.7)	151 (99.3)	[28]
	Rewari	2009	152	210.0	0 (0.0)	0 (0.0)	4 (2.6)	148 (97.4)	[28]
	Jhajar	2009	152	210.0	0 (0.0)	0 (0.0)	1 (0.7)	151 (99.3)	[28]
	Rohtak	2009	149	210.0	0 (0.0)	1 (0.7)	0 (0.0)	148 (99.3)	[28]
	Gurgaon	2009	152	200.0	0 (0.0)	0 (0.0)	16 (10.5)	136 (89.5)	[28]
	Faridabad	2009	176	200.0	0 (0.0)	0 (0.0)	4 (2.3)	172 (97.7)	[28]
	Ambala	2013	270	100.0	-	2 (0.7)	5 (1.8)	263 (97.5)	[71]
Himachal Pradesh	Kangra	1997	245	165.0	6 (2.4)	10 (4.1)	42 (17.1)	187 (76.3)	[29]
	Hamirpur	1998	787	135.0	69 (8.8)	65 (8.3)	137 (17.4)	516 (65.6)	[30]
	Kinnaur	1998	226	195.0	3 (1.3)	13 (5.8)	24 (10.6)	186 (82.3)	[31]
	Solan	1999	720	150.0	21 (2.9)	42 (5.8)	142 (19.7)	515 (71.5)	[32]
	Kullu	2000	147	150.0	0 (0.0)	1 (0.7)	3 (8.8)	133 (90.5)	[33]
	Kangra	2000	394	175.0	8 (2.0)	14 (3.6)	54 (13.7)	318 (80.7)	[34]
	Mandi	2004	2001	150.0	NA	NA	NA	NA	[16]
	Shimla	2003	195	140.0	3 (1.5)	11 (5.6)	47 (24.1)	134 (68.8)	[15]
	Kullu	2003	193	205.0	4 (2.1)	13 (6.7)	16 (8.3)	160 (82.9)	[15]
	Kullu	2005	289	100.0	1 (0.3)	4 (1.4)	55 (19.0)	229 (79.2)	[35]
	Mandi	2005	214	>200.0	0 (0)	0 (0)	4 (1.9)	210 (98.1)	[35]
	Una	2005	206	>200.0	0 (0)	0 (0)	2 (1.0)	204 (99.0)	[35]
	Kannaur	2005	215	>200.0	0 (0)	1 (0.5)	7 (3.3)	207 (96.2)	[35]
	Kullu	2005	208	>200.0	0 (0)	6 (2.9)	22 (10.6)	180 (86.5)	[35]
	Shimla	2005	187	>200.0	4 (2.1)	2 (1.1)	7 (3.7)	174 (93.0)	[35]
	Lahaul Spiti	2005	211	>200.0	0 (0)	1 (0.5)	3 (1.4)	207 (98.1)	[35]
	Solan	2005	223	>200.0	0 (0)	3 (1.3)	15 (6.7)	205 (91.9)	[35]
	Kangra	2005	225	>200.0	0 (0)	7 (3.1)	33 (14.7)	185 (82.2)	[35]
	Hamirpur	2005	238	>200.0	0 (0)	0 (0)	5 (2.1)	233 (97.9)	[35]
	Sirmour	2005	209	>200.0	2 (0.9)	3 (1.4)	35 (15.9)	180 (81.8)	[35]
	Chamba	2005	218	>200.0	0 (0)	3 (1.4)	35 (15.9)	180 (81.8)	[35]
	Bilaspur	2005	220	>200.0	0 (0)	0 (0)	4 (1.9)	205 (98.1)	[35]
	Kangra	2007	1952	150.0	69 (3.5)	74 (3.8)	278 (14.2)	1531 (78.5)	[36]
	Kangra	2013	463	200.0	-	10 (2.2)	66 (14.3)	387 (83.5)	[72]
	Solan	2013	513	62.5	-	238 (46.4)	51 (9.9)	224 (43.7)	[73]
	Kullu	2013	532	175.0	-	32 (6.0)	103 (19.4)	397 (74.6)	[74]
	Kangra	2014	368	200.0	-	-	69.0 (18.8)	299 (81.2)	[75]
	Solan	2014	311	130.0	-	80 (25.7)	40 (12.9)	191 (61.2)	[75]
	Kullu	2014	439	149.0	-	286 (65.1)	32.0 (7.3)	121 (27.6)	[75]
Jharkhand	Palamu	2003	209	120.0	16 (7.7)	32 (15.3)	43 (20.6)	118 (56.5)	[15]
	All districts	2008	1121	173.2	42 (3.7)	70 (6.3)	184 (16.4)	825 (73.6)	[37]
Jammu and Kashmir	Kupwara	2003	206	300.0	0.0 (0.0)	2 (1.0)	14 (6.8)	190 (92.2)	[15]
	Jammu	2008	134	96.5	NA	9 (6.7)	57 (42.5)	NA	[38]
	Kashmir	2014	208	104.0	NA	NA	NA	NA	[76]
Karnataka	Manipal	2002	722	<100	NA	NA	NA	NA	[39]
	Chickmagalur	2003	210	140.0	0.0 (0.0)	22 (10.5)	43 (20.6)	145 (68.9)	[15]
	Bangalore	2003	210	130.0	1 (0.5)	26 (12.4)	47 (22.4)	136 (64.7)	[15]
	Shimoga	2005	96	30.0	30 (31.3)	23 (24.0)	33 (34.4)	10 (10.4)	[40]
	Dharwad	2005	99	100.0	3 (3.0)	5 (5.1)	40 (40.4)	51 (51.5)	[40]
	Haveri	2005	99	100.0	0 (0.0)	12 (12.1)	32 (32.3)	55 (55.6)	[40]
	Udupi	2005	84	>200.0	0 (0.0)	1 (1.2)	6 (7.1)	77 (91.7)	[40]
	Dakshina Kannada	2005	97	70.0	17 (17.5)	8 (8.2)	42 (43.3)	30 (30.9)	[40]
	Chikmagalur	2005	100	150.0	2 (2.0)	5 (5.0)	19 (19.0)	74 (74.0)	[40]
	Gulbarga	2005	94	70.0	4 (4.3)	19 (20.2)	43 (45.7)	28 (29.8)	[40]
	Belgaum	2005	100	100.0	1 (1.0)	13 (13.0)	28 (28.0)	58 (58.0)	[40]
	Uttara Kannada	2005	100	100.0	11 (11.0)	15 (15.0)	21 (21.0)	53 (53.0)	[40]
	Bijapur	2005	76	85.0	9 (11.8)	0 (0.0)	32 (42.1)	35 (46.1)	[40]
	Raichur	2005	93	120.0	0 (0.0)	3 (3.2)	21 (22.6)	69 (74.2)	[40]

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Table 1: *Contd...*

State	Name of the district	Year	Number of urine samples	Median (μg/l)	Urinary iodine excretion levels (μg/l)				Reference
					<20.0	20.0-49.9	50.0-99.9	≥100.0	
	Davangere	2005	90	52.0	19 (21.1)	17 (18.9)	19 (21.1)	35 (38.9)	[40]
	Chitradurga	2005	71	>200.0	8 (11.3)	0 (0.0)	4 (5.6)	59 (83.1)	[40]
	Tumkur	2005	97	100.0	0 (0.0)	5 (5.2)	29 (29.9)	63 (64.9)	[40]
	Kodagu	2005	96	30.0	25 (26.0)	34 (35.4)	21 (21.9)	16 (16.7)	[40]
	Bangalore (rural)	2005	94	100.0	5 (5.3)	3 (3.2)	23 (24.5)	63 (67.0)	[40]
	Madya	2005	98	120.0	0 (0.0)	2 (2.0)	30 (30.6)	66 (67.3)	[40]
	Bellary	2005	95	65.0	5 (5.3)	14 (14.7)	44 (46.3)	32 (33.7)	[40]
	Koppal	2005	86	100.0	3 (3.5)	4 (4.7)	24 (27.9)	55 (64.0)	[40]
	Kolar	2005	101	95.0	2 (2.0)	7 (6.9)	48 (47.5)	44 (43.6)	[40]
Kerala	Kottayam	2002	251	175.0	16 (16.4)	15 (6.0)	52 (20.7)	168 (66.9)	[41]
	Ernakulam	2003	210	143.0	5 (2.5)	23 (11.1)	49 (23.5)	132 (62.9)	[15]
	Wayanad	2003	210	90.0	12 (5.7)	70 (33.3)	26 (12.4)	102 (48.6)	[15]
	Alappuza	2006	94	100.0	6 (6.4)	4 (4.3)	31 (33.0)	53 (56.4)	[42]
	Idduki	2006	72	55.0	15 (20.8)	15 (20.8)	27 (37.5)	15 (20.8)	[42]
	Kottayam	2006	99	85.0	7 (7.1)	24 (24.2)	19 (19.2)	49 (49.5)	[42]
	Calicut	2006	56	120.0	1 (1.8)	3 (5.4)	12 (21.4)	40 (71.4)	[42]
	Malappuram	2006	88	150.0	8 (9.1)	12 (13.6)	12 (13.6)	56 (63.6)	[42]
	Kannur	2006	90	150.0	0 (0.0)	0 (0.0)	0 (0.0)	90 (100.0)	[42]
	Kasargod	2006	92	75.0	34 (37.0)	3 (3.3)	22 (23.9)	33 (35.9)	[42]
	Wyanad	2006	98	100.0	8 (8.2)	7 (7.1)	29 (29.6)	54 (55.1)	[42]
Madhya Pradesh	Jabalpur	2001	1205	80-150	NA	NA	135 (11.2)	1069 (88.7)	[43]
Maharashtra	Raigarh	2001	2092	100.0	NA	NA	NA	NA	[8]
	Sindhdurg	2003	210	125.0	15 (7.1)	22 (10.5)	48 (22.9)	125 (59.5)	[15]
	Kolhapur	2003	209	65.0	49 (23.3)	28 (13.2)	64 (30.7)	69 (32.8)	[15]
	Nagpur	2010	109	215.0	NA	NA	NA	NA	[44]
Manipur	Bishnupur	2001	2076	106.0	NA	NA	NA	NA	[8]
	Imphal	2003	120	125.0		NA	NA	NA	[45]
	Bishnupur	2003	210	185.0	2 (1.0)	16 (7.6)	34 (16.2)	158 (75.2)	[15]
	Chandel	2003	189	250.0	4 (2.1)	13 (6.9)	23 (12.2)	149 (78.8)	[15]
Mizoram	Aizwal	2003	210	161.0	2 (1.0)	7 (3.3)	33 (15.7)	168 (80.0)	[15]
	Chhintuipui	2003	210	170.0	1 (0.5)	12 (5.7)	34 (16.2)	163 (77.6)	[15]
Nagaland	Mon	2003	207	120.0	5 (2.4)	37 (17.9)	49 (23.7)	116 (56.0)	[15]
Orissa	Cuttack	2003	210	110.0	20 (9.5)	27 (12.9)	41 (19.5)	122 (58.1)	[15]
	Sundargarh	2003	208	103.0	25 (12.0)	27 (13.0)	50 (24.0)	106 (51.0)	[15]
	Puri	2004	145	125.0	2 (1.4)	8 (5.5)	33 (22.8)	102 (70.3)	[16]
	All districts	2007	1200	85.4	NA	386 (32.2)	NA	NA	[46]
	Bhubaneswar	2007	411	50.0	NA	NA	352 (85.7)	NA	[47]
	Cuttack	2009	168	64.5	NA	125 (74.3)	NA	43 (25.7)	[48]
Pondicherry	Pondicherry	1998	187	145.0	3 (1.6)	6 (3.2)	45 (24.1)	133 (71.1)	[49]
	Kariakal	2004	80	150.0	0 (0.0)	3 (3.8)	9 (11.3)	68 (85.0)	[16]
	Yanam	2004	100	200.0	0 (0.0)	0 (0.0)	15 (15.0)	85 (85.0)	[16]
	Mahe	2004	100	65.0	5 (5.0)	27 (27.0)	34 (34.0)	34 (34.0)	[16]
	Pondicherry	2007	97	200.0	0 (0.0)	2 (2.1)	7 (7.2)	88 (90.7)	[50]
	Pondicherry	2014	2581	142.9	NA	NA	NA	NA	[77]
Punjab	Gurudaspur	2003	202	70.0	38 (18.8)	28 (13.9)	57 (28.2)	79 (39.1)	[15]
Rajasthan	Bikaner	1997	400	155.0	12 (3.0)	36 (9.0)	73 (18.0)	279 (70.0)	[51]
	Bikaner	2001	1824	118.0	NA	NA	NA	NA	[8]
	Bharatpur	2003	450	155.0	5 (1.1)	5 (1.1)	35 (7.8)	405 (90.0)	[52]
	Udaipur	2003	300	200.0	NA	NA	NA	NA	[53]
	Bikaner	2003	203	120.0	19 (9.4)	17 (8.4)	48 (23.6)	119 (58.6)	[15]
	Kota	2003	201	155.0	33 (16.4)	15 (7.5)	32 (15.9)	122 (60.2)	[15]
	All districts	2008	1200	139.0	NA	NA	NA	NA	[54]
	All districts	2008	360	127.0	NA	NA	NA	NA	[78]
	All districts	2008	1200	139.0	NA	NA	NA	NA	[78]
Sikkim	East Gangtok	2003	204	137.0	17 (8.3)	22 (10.8)	32 (15.7)	133 (65.2)	[15]
	North Mangam	2003	200	57.0	51 (25.5)	27 (13.5)	56 (28.0)	66 (33.0)	[15]
Tamil Nadu	Dindigul	2003	210	145.0	5 (2.4)	19 (9.1)	36 (17.2)	150 (71.3)	[15]
	Trichy	2003	210	275.0	0 (0.0)	0 (0.0)	14 (6.7)	196 (93.3)	[15]
	Nagapattinam	2004	100	150.0	0 (0.0)	4 (4.0)	2 (2.0)	94 (94.0)	[55]
	Cuddalore	2004	100	>200.0	0 (0.0)	0 (0.0)	3 (3.0)	97 (97.0)	[55]
	Nilgiris	2004	56	180.0	0 (0.0)	4 (7.1)	6 (10.7)	46 (82.1)	[55]

Contd...

Table 1: *Contd...*

State	Name of the district	Year	Number of urine samples	Median (µg/l)	Urinary iodine excretion levels (µg/l)				Reference
					<20.0	20.0-49.9	50.0-99.9	≥100.0	
	Erode	2004	85	155.0	0 (0.0)	0 (0.0)	10 (11.8)	75 (88.2)	[55]
	Dindigul	2004	90	150.0	0 (0.0)	9 (10.0)	21 (23.3)	60 (66.7)	[55]
	Pudukkotai	2004	56	>200.0	0 (0.0)	1 (2.8)	3 (5.4)	52 (92.9)	[55]
	Thanjavur	2004	89	150.0	0 (0.0)	2 (2.2)	10 (11.2)	77 (86.5)	[55]
	Sivaganga	2004	63	155.0	0 (0.0)	0 (0.0)	8 (12.7)	55 (87.3)	[55]
	Perambalor	2004	157	85.0	13 (8.3)	31 (19.7)	35 (22.3)	78 (49.7)	[55]
	Trichy	2004	112	>200.0	1 (0.9)	0 (0.0)	2 (1.8)	109 (97.3)	[55]
	Karur	2004	110	180.0	0 (0.0)	1 (0.9)	7 (6.4)	102 (92.7)	[55]
	Madurai	2004	107	>200.0	2 (1.9)	0 (0.0)	3 (2.8)	102 (95.3)	[55]
	Kancheepuram	2004	88	>200.0	3 (3.4)	0 (0.0)	1 (1.1)	84 (95.5)	[55]
	Thiruvannamalai	2004	72	120.0	0 (0.0)	4 (5.6)	22 (30.6)	46 (63.9)	[55]
	Villupuram	2004	67	100.0	1 (1.5)	1 (1.5)	21 (31.3)	44 (65.7)	[55]
	Dharmapuri	2004	70	195.0	1 (1.4)	1 (1.4)	6 (8.6)	62 (88.6)	[55]
	Vellore	2004	80	150.0	0 (0.0)	0 (0.0)	14 (17.5)	66 (82.5)	[55]
	Tiruvallore	2004	92	>200.0	0 (0.0)	0 (0.0)	2 (2.2)	90 (97.8)	[55]
	Tiruvarur	2004	94	>200.0	0 (0.0)	1 (1.0)	15 (16.0)	78 (83.0)	[55]
	24 districts	2004	1440	<100	NA	NA	NA	NA	[79]
	All districts	2010	1228	89.5	NA	NA	NA	NA	[80]
Tripura	North Tripura	2002	1123	>100.0	NA	NA	NA	NA	[56]
	Tripura	2004	133	175.0	0 (0.0)	19 (14.3)	27 (20.3)	87 (65.4)	[16]
Uttarakhand	Udham Singh nagar	2000	770	98.0	23 (3.0)	66 (8.6)	231 (30.0)	NA	[57]
	Dehradun	2001	1617	127.0	NA	NA	NA	NA	[8]
	Nainital	2003	194	110.0	15 (7.7)	30 (15.5)	43 (22.2)	106 (54.6)	[15]
	Pauri	2004	100	175.0	2 (2.0)	2 (2.0)	13 (13.0)	83 (83.0)	[16]
	Pithoragarh	2004	154	200.0	0 (0.0)	2 (1.2)	17 (11.4)	135 (87.6)	[16]
	Uttar Kashi	2004	61	200.0	6 (9.8)	2 (3.2)	7 (11.4)	46 (75.4)	[16]
	Nainital	2014	611	125.0	0	72 (11.8)	152 (24.9)	387 (63.3)	[81]
	Udham Singh nagar	2014	587	150.0	0	35 (6.0)	124 (21.2)	427 (72.7)	[82]
	Pauri	2014	580	115.0	-	147 (25.4)	100 (17.2)	333 (57.4)	[83]
	Nainital	2014	468	117.5	-	4 (0.9)	149 (31.8)	315 (67.3)	[84]
	Udham Singh nagar	2014	532	124.0	-	62 (11.7)	102 (19.2)	368 (69.0)	[84]
	Pauri	2014	404	110.0	-	97 (24.0)	85 (21.0)	222 (54.9)	[84]
Uttar Pradesh	Lakhimpur Kheri	2001	2003	90.0	NA	NA	NA	NA	[8]
	Badaun	2001	1978	118.0	NA	NA	NA	NA	[8]
	Mainpuri	2001	1050	90.0	NA	NA	NA	NA	[8]
	Shahjhanpur	2003	182	75.0	9 (4.9)	21 (11.5)	87 (47.8)	65 (35.7)	[15]
	Shahranpur	2003	135	75.0	5 (3.7)	33 (24.4)	48 (35.6)	49 (36.3)	[15]
	Meerut	2004	710	150.0	38 (5.4)	21 (2.9)	142 (20.2)	509 (71.7)	[16]
	Saharanpur	2004	192	200.0	1 (0.4)	5 (2.6)	12 (6.2)	174 (90.6)	[16]
	Bareilly	2004	82	102.0	11 (13.4)	18 (21.9)	10 (12.3)	45 (52.4)	[16]
	Agra	2004	92	175.0	0 (0.0)	0 (0.0)	10 (10.8)	82 (89.1)	[16]
	Kanpur	2004	72	105.0	1 (1.4)	2 (2.8)	25 (34.7)	44 (61.1)	[16]
	Lakhimpur	2004	128	50.0	18 (14.1)	18 (14.1)	39 (30.4)	53 (41.4)	[16]
	Lalitpur	2004	109	135.0	0 (0.0)	10 (9.3)	28 (25.7)	61 (55.9)	[16]
	Sidharth nagar	2004	148	100.0	15 (10.1)	13 (8.8)	37 (25.0)	83 (56.1)	[16]
	Padrona	2004	80	200.0	0 (0.0)	0 (0.0)	5 (6.2)	75 (93.8)	[16]
	Sultanpur	2004	103	100.0	1 (1.0)	13 (12.6)	37 (35.9)	52 (50.5)	[16]
	Gorakhpur	2004	147	150.0	7 (4.8)	3 (2.0)	17 (11.6)	120 (81.6)	[16]
	Varanasi	2004	107	100.0	8 (16.8)	0 (0.0)	30 (28.0)	59 (55.1)	[16]
	Meerut	2004	710	150.0	8 (5.4)	21 (2.9)	142 (20.0)	509 (71.7)	[16]
	Sidharth nagar	2008	200	96.0	NA	NA	NA	NA	[85]
	Sidharth nagar	2009	240	60.0	42 (17.5)	NA	NA	NA	[58]
	Gonda	2010	1236	100.0	99 (8.0)	155 (12.5)	337 (27.3)	645 (52.2)	[59]
West Bengal	Darjeeling	2003	206	110.0	10 (4.9)	13 (6.3)	67 (32.5)	116 (56.3)	[15]
	Jalpaiguri	2003	208	120.0	21 (10.1)	29 (9.1)	34 (16.3)	134 (64.4)	[15]
	South 24 Parganas	2005	520	225.0	NA	NA	NA	NA	[60]
	Dakshin Dinajpur	2005	2250	16.0	372 (16.5)	NA	NA	NA	[61]
	North 24 Parganas	2006	363	160.0	NA	NA	10 (6.0)	150 (94.0)	[62]
	Purulia	2006	2400	92.5125.0	759 (31.6)	NA	NA	NA	[63]
	Howrah	2008	200	250.0	NA	NA	NA	NA	[64]
	Medinipur	2008	354	115.0	0	0	83 (23.4)	271 (76.6)	[86]
	Darjeeling	2014	358	156.0	0	1 (0.28)	2 (0.56)	355 (99.16)	[87]

NA: Nonavailable

Table 2: Iodine content of salt samples collected at beneficiary level in selected districts of India

State	Name of the district	Year	Number of salt samples	Iodine content of salt (ppm)		Reference
				<15	15 ppm and more	
Assam	Dibrugarh	2001	300	170 (56.7)	130 (43.3)	[8]
	Nagaon	2001	691	2 (0.3)	689 (99.7)	[8]
	Dibrugarh	2003	211	39 (18.5)	172 (81.5)	[15]
	Dubri	2003	210	72 (34.3)	138 (65.7)	[15]
	Changlong	2003	196	98 (50.0)	98 (50.0)	[15]
Andaman and Nicobar	Andaman and Nicobar	2004	211	27 (12.8)	184 (87.2)	[16]
Andhra Pradesh	Mehboob nagar	2001	172	164 (95.3)	8 (4.7)	[8]
	Adilabad	2003	210	155 (73.8)	55 (26.2)	[15]
	East Godavari	2003	210	190 (90.5)	20 (9.5)	[15]
	Vijayanagram	2004	211	165 (78.2)	46 (21.8)	[17]
	Srikakulam	2004	205	178 (86.8)	27 (13.2)	[17]
	East Godavari district	2004	152	142 (93.4)	10 (6.6)	[17]
	West Godavari district	2004	148	127 (85.6)	21 (14.2)	[17]
	Guntur	2004	150	103 (68.7)	47 (31.3)	[17]
	Prakasam	2004	150	136 (90.6)	14 (9.3)	[17]
	Warangal	2004	158	136 (86.1)	22 (14.0)	[17]
	Adilabad	2004	155	105 (67.3)	51 (32.7)	[17]
	Kurnool	2004	106	97 (91.5)	9 (8.4)	[17]
	Mehboob nagar	2004	116	103 (88.8)	13 (11.2)	[17]
	Chittor	2004	183	145 (79.2)	38 (20.8)	[17]
	Nellore	2004	119	116 (97.4)	3 (2.5)	[17]
	Krishna	2004	150	113 (75.3)	37 (24.6)	[17]
	Khammam	2004	150	112 (74.7)	38 (25.3)	[17]
	Nalgonda	2004	150	131 (87.3)	19 (12.6)	[17]
	Karim nagar	2004	150	79 (52.6)	71 (47.4)	[17]
	Medak	2004	150	98 (65.4)	52 (34.7)	[17]
	Hyderabad	2004	200	118 (58.7)	82 (40.8)	[17]
	Nizamabad	2004	200	156 (78.0)	44 (22.0)	[17]
	Rangareddy	2004	204	196 (96.1)	8 (3.9)	[17]
	Anatpur	2004	155	147 (90.8)	8 (5.1)	[17]
	Cuddapah	2004	155	137 (88.3)	18 (11.6)	[17]
	Vishakapatnam	2004	205	195 (95.0)	10 (4.9)	[17]
Bihar	West Champaran	1997	164	108 (65.9)	56 (34.1)	[18]
	East Champaran	1997	292	78 (26.7)	214 (73.3)	[18]
	Munger	1998	198	40 (20.2)	216 (79.8)	[19]
	Muzafarpur	1998	210	42 (20.0)	168 (80.0)	[19]
	Vaishali	1998	188	32 (17.0)	156 (83.0)	[19]
	Sahibganj	1998	345	273 (79.1)	72 (20.9)	[19]
	Gaya	2001	288	281 (97.6)	7 (2.4)	[8]
	Patna	2001	764	398 (52.1)	366 (47.9)	[8]
	West Champaran	2003	210	103 (49.0)	107 (51.0)	[15]
	Palamu	2004	102	56 (54.9)	46 (45.1)	[16]
	All districts	2006	1169	700 (59.9)	469 (40.1)	[7]
Chattisgarh	Shahdol	2003	205	150 (73.2)	55 (26.8)	[15]
	Sarguja	2003	239	164 (68.6)	75 (31.4)	[15]
Delhi	Delhi	2004	1307	455 (34.8)	852 (65.2)	[22]
	Delhi	2005	1854	785 (42.3)	1069 (57.7)	[23]
	Delhi	2010	1230	138 (11.2)	1092 (88.8)	[25]
	Delhi	2011	1230	1092 (88.8)	138 (11.2)	[66]
	Delhi	2013	1393	181 (13.0)	1212 (87.0)	[67]
Goa	Goa	1996	133	94 (70.9)	39 (29.1)	[19]
Gujarat	Surat	2003	208	151 (72.6)	57 (27.4)	[15]
	Valsad	2003	209	145 (69.3)	64 (30.7)	[15]
	Panchmahal	2007	15900	7266 (45.7)	8634 (54.3)	[26]
	Saurashtra	2010	840	160 (19)	680 (81)	[26]
	Kutch	2011	840	65 (7.7)	775 (92.3)	[68]
	Bharuch	2012	840	59 (7.0)	781 (93.0)	[69]
Haryana	Sonepat	2003	210	40 (19.1)	170 (80.9)	[15]
	Ambala	2009	139	47 (34.0)	92 (66.0)	[28]
	Bhiwani	2009	94	66 (70.0)	28 (30.0)	[28]
	Faridabad	2009	135	73 (54.0)	62 (46.0)	[28]

Contd...

Table 2: *Contd...*

State	Name of the district	Year	Number of salt samples	Iodine content of salt (ppm)		Reference
				<15	15 ppm and more	
	Hissar	2009	152	122 (80.0)	30 (20.0)	[28]
	Jind	2009	149	106 (70.0)	43 (30.0)	[28]
	Kaithal	2009	239	98 (41.0)	141 (59.0)	[28]
	Karnal	2009	77	24 (31.0)	53 (69.0)	[28]
	Kurukshetra	2009	174	53 (30.0)	121 (70.0)	[28]
	Mahendergarh	2009	174	147 (84.5)	27 (15.5)	[28]
	Panipat	2009	185	18 (10.0)	167 (90.0)	[28]
	Rewari	2009	93	49 (52.7)	44 (47.3)	[28]
	Rohtak	2009	664	388 (52.5)	276 41.5)	[28]
	Sirsa	2009	146	94 (66.4)	52 (35.6)	[28]
	Sonepat	2009	188	41 (22.0)	147 (78.0)	[28]
	Yamuna nagar	2009	142	36 (25.0)	106 (75.0)	[28]
	Ambala	2013	540	93 (11.7)	447 (88.3)	[71]
Himachal Pradesh	Hamirpur	1996	242	390 (13.3)	217 (89.6)	[30]
	Kangra	1997	372	87 (23.0)	285 (77.0)	[29]
	Kinnaur	1998	242	25 (10.3)	217 (89.6)	[31]
	Solan	1999	1481	395 (26.7)	1086 (73.3)	[32]
	Kangra	2000	746	49 (6.6)	697 (93.4)	[34]
	Mandi	2001	293	103 (35.2)	190 (64.8)	[8]
	Shimla	2003	204	70 (34.2)	134 (65.8)	[15]
	Kullu	2003	204	50 (24.5)	154 (75.5)	[15]
	Kullu	2005	113	17 (15.0)	96 (84.9)	[35]
	Mandi	2005	191	40 (21.0)	151 (79.1)	[35]
	Una	2005	245	70 (28.5)	175 (71.4)	[35]
	Kinnaur	2005	203	9 (4.4)	194 (95.6)	[35]
	Kullu	2005	214	29 (13.5)	185 (86.4)	[35]
	Shimla	2005	179	22 (12.3)	157 (87.7)	[35]
	Lahol Spiti	2005	201	61 (30.4)	140 (69.7)	[35]
	Solan	2005	220	29 (13.2)	191 (86.8)	[35]
	Kangra	2005	241	30 (12.4)	211 (87.6)	[35]
	Hamirpur	2005	217	46 (21.2)	171 (78.8)	[35]
	Sirmour	2005	193	41 (20.4)	152 (78.8)	[35]
	Chamba	2005	214	60 (28.0)	154 (72.0)	[35]
	Bilaspur	2005	207	19 (9.2)	188 (90.8)	[35]
	Kangra	2007	1175	149 (12.7)	1026 (87.3)	[36]
	Kangra	2013	327	269 (82.3)	58 (17.7)	[72]
	Solan	2013	568	337 (60.5)	220 (39.5)	[73]
	Kullu	2013	681	332 (48.7)	349 (51.3)	[74]
	Kangra	2014	511	162 (31.7)	349 (68.3)	[75]
	Kullu	2014	436	173 (39.7)	263 (60.3)	[75]
	Solan	2014	336	173 (51.5)	163 (48.5)	[75]
Jharkhand	Palamu	2003	210	163 (77.6)	47 (22.4)	[15]
	Entire state	2008	1150	411 (35.8)	739 (64.2)	[37]
Jammu and Kashmir	Baramulla	2000	300	52 (17.3)	248 (82.7)	[8]
	Srinagar	2001	298	52 (17.4)	246 (82.6)	[8]
	Kupwara	2003	208	62 (29.8)	146 (70.2)	[15]
	Jammu	2008	99	2 (1.9)	97 (98.1)	[38]
Karnataka	Manipal	2002	722	373 (51.7)	349 (48.3)	[39]
	Chickmagalur	2003	210	133 (63.3)	77 (36.7)	[15]
	Bangalore	2003	210	160 (76.2)	50 (23.8)	[15]
	Wayanad	2003	210	90 (42.9)	120 (57.1)	[15]
	Shimoga	2005	165	126 (76.3)	39 (23.6)	[40]
	Dharwad	2005	150	99 (66.0)	51 (34.0)	[40]
	Haveri	2005	150	140 (93.3)	10 (6.7)	[40]
	Udupi	2005	149	126 (84.5)	23 (15.4)	[40]
	Dakshina Kannada	2005	151	133 (88.1)	18 (12.0)	[40]
	Chikmagalur	2005	150	101 (67.3)	47 (32.7)	[40]
	Gulbarga	2005	150	150 (100.0)	0 (0.0)	[40]
	Belgaum	2005	200	169 (84.5)	31 (13.5)	[40]
	Uttara Kannada	2005	201	212 (90.1)	20 (10.0)	[40]
	Bijapur	2005	190	174 (91.5)	16 (8.4)	[40]

Contd...

Table 2: *Contd...*

State	Name of the district	Year	Number of salt samples	Iodine content of salt (ppm)		Reference
				<15	15 ppm and more	
	Bangalore (urban)	2005	178	104 (58.5)	74 (41.6)	[40]
	Davangere	2005	156	151 (96.8)	5 (3.2)	[40]
	Chitradurga	2005	156	102 (65.4)	54 (34.6)	[40]
	Tumkur	2005	150	147 (98.0)	3 (2.0)	[40]
	Kodagu	2005	150	124 (82.7)	26 (17.3)	[40]
	Bangalore (rural)	2005	163	116 (71.1)	47 (28.4)	[40]
	Madya	2005	154	121 (78.6)	33 (21.4)	[40]
	Hassan	2005	152	146 (96.1)	6 (3.9)	[40]
	Mysore	2005	152	112 (73.6)	40 (26.3)	[40]
	Bellary	2005	152	148 (97.3)	4 (2.6)	[40]
	Koppal	2005	152	146 (96.1)	6 (3.9)	[40]
	Chamaraja nagar	2005	158	137 (86.7)	21 (13.3)	[40]
	Kolar	2005	150	142 (94.7)	8 (5.3)	[40]
	Chamarajanagar	2013	3757	1067 (28.4)	2690 (71.6)	[88]
	Coorg	2014	395	292 (73.92)	103 (26.08)	[89]
	Mysore	2014	248	114 (45.92)	134 (54.08)	[89]
Kerala	Palghat	1997	149	69 (46.2)	80 (53.7)	[19]
	Ernakulam	1998	199	22 (11.0)	177 (89.0)	[19]
	Kottayam	2002	420	165 (39.2)	255 (60.6)	[41]
	Ernakulam	2003	210	139 (66.2)	71 (33.8)	[15]
	Kollam	2006	155	58 (37.5)	97 (62.6)	[42]
	Pathanmthita	2006	146	66 (45.2)	80 (54.8)	[42]
	Alappuza	2006	148	78 (52.7)	70 (47.3)	[42]
	Idduki	2006	152	103 (67.8)	49 (32.2)	[42]
	Kottayam	2006	153	76 (49.7)	77 (50.4)	[42]
	Trissur	2006	150	91 (60.6)	59 (39.3)	[42]
	Palakkad	2006	151	133 (48.0)	18 (11.9)	[42]
	Ernakulum	2006	156	109 (69.8)	47 (30.2)	[42]
	Calicut	2006	146	67 (45.9)	79 (54.1)	[42]
	Malappuram	2006	150	6 (4.0)	144 (96.0)	[42]
	Kannur	2006	153	102 (66.7)	51 (33.3)	[42]
	Kasargod	2006	149	121 (81.2)	28 (18.7)	[42]
	Wyanad	2006	146	108 (74.0)	38 (26.0)	[42]
	Thiruvantha-puram	2006	156	70 (44.8)	86 (55.2)	[42]
Madhya Pradesh	Bastar	1996	201	58 (28.9)	143 (71.1)	[19]
	Dhar	1996	168	47 (28.0)	121 (72.0)	[19]
	Gwalior	1996	321	62 (19.3)	259 (80.6)	[19]
	Ratlam	1996	199	131 (37.7)	124 (62.3)	[19]
	Shahdol	1996	153	37 (24.1)	116 (93.8)	[19]
	Vidisha	1996	169	79 (46.5)	90 (53.2)	[19]
	Indore	1996	212	96 (45.3)	116 (75.8)	[19]
	Morena	1996	185	88 (47.6)	57 (52.4)	[19]
	Sidhi	1996	168	82 (48.8)	86 (51.2)	[19]
	Sihore	1996	216	77 (35.6)	139 (64.4)	[19]
Maharashtra	Raigarh	2001	300	182 (60.7)	118 (39.3)	[8]
	Sindhdurg	2003	240	113 (47.1)	127 (52.9)	[15]
	Kolhapur	2003	197	116 (58.9)	81 (41.1)	[15]
Manipur	Bishnupur	2001	651	14 (2.2)	637 (97.8)	[8]
	Bishnupur	2003	210	11 (5.5)	199 (94.8)	[15]
	Chandel	2003	189	16 (8.4)	173 (91.6)	[15]
	Imphal	2003	105	19 (18)	86 (82)	[15]
Mizoram	Aizwal	2003	210	26 (12.4)	184 (87.6)	[15]
	Chhintuipui	2003	210	71 (33.8)	139 (66.2)	[15]
Nagaland	Mon	2003	210	167 (79.5)	43 (20.5)	[15]
Orissa	Cuttack	2003	210	162 (77.1)	48 (22.9)	[15]
	Sundergarh	2003	210	163 (77.6)	47 (22.4)	[15]
	All districts	2007	1200	660 (55)	540 (45)	[46]
	Bhubaneswar	2007	368	180 (49)	188 (51)	[47]
	Cuttack	2009	336	134 (39.9)	202 (60.1)	[48]
Pondicherry	Pondicherry	1998	201	138 (68.6)	63 (31.4)	[52]
	Kariakal	2004	150	147 (98.0)	3 (2.0)	[16]
	Yanam	2004	150	129 (86.0)	21 (14.0)	[16]

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Table 2: *Contd...*

State	Name of the district	Year	Number of salt samples	Iodine content of salt (ppm)		Reference
				<15	15 ppm and more	
	Pondicherry	2004	150	140 (93.4)	10 (6.6)	[16]
	Pondicherry	2007	290	214 (73.8)	76 (26.2)	[50]
	Pondicherry	2014	2581	1032 (40.0)	1549 (60.0)	[77]
Punjab	Amritasr	1998	170	79 (46.5)	34 (53.5)	[19]
	Bhatinda	1998	417	107 (25.6)	195 (66.8)	[19]
	Faridkot	1998	164	36 (22.0)	128 (78)	[19]
	Fatehgarh	1998	205	73 (35.6)	132 (64.4)	[19]
	Ferozpur	1998	196	59 (29.1)	137 (69.8)	[19]
	Gurdaspur	1998	199	43 (21.6)	156 (78.3)	[19]
	Hoshiarpur	1998	341	61 (17.9)	280 (82.1)	[19]
	Jalandhar	1998	201	47 (23.4)	157 (78.1)	[19]
	Kapurthala	1998	240	88 (36.7)	152 (63.3)	[19]
	Ludhiana	1998	201	31 (16.9)	167 (83.1)	[19]
	Mansa	1998	395	264 (66.9)	131 (33.2)	[19]
	Moga	1998	204	24 (11.8)	180 (88.2)	[19]
	Muktsar	1998	138	15 (10.9)	123 (89.1)	[19]
	Navashahar	1998	208	24 (11.5)	184 (88.4)	[19]
	Patiala	1998	144	97 (67.4)	47 (32.6)	[19]
	Ropar	1998	197	14 (7.1)	183 (92.9)	[19]
	Sangrur	1998	249	47 (18.9)	202 (81.2)	[19]
	Gurudaspur	2003	206	116 (56.3)	90 (43.7)	[15]
Rajasthan	Bikaner	1997	526	210 (39.9)	316 (60.1)	[51]
	Bikaner	2001	35	29 (82.9)	6 (17.1)	[8]
	Udaipur	2003	281	42 (15)	239 (85)	[53]
	Bikaner	2003	211	184 (87.2)	27 (12.8)	[15]
	Kota	2003	187	142 (75.9)	45 (24.1)	[15]
	All districts	2008	1157	751 (64.9)	406 (35.1)	[54]
Sikkim	East Gangtok	2003	210	64 (30.5)	146 (69.5)	[15]
	North Mangam	2003	210	63 (30.0)	147 (70.0)	[15]
Tamil Nadu	Dindigul	2003	210	175 (83.3)	35 (16.7)	[15]
	Trichy	2003	210	189 (90.0)	21 (10.0)	[15]
	Nagapattinam	2004	150	149 (99.3)	1 (0.7)	[55]
	Cuddalore	2004	149	143 (95.9)	6 (4.1)	[55]
	Nilgiris	2004	150	113 (65.5)	37 (24.5)	[55]
	Coimbatore	2004	150	126 (84.1)	24 (15.9)	[55]
	Erode	2004	150	114 (76.2)	36 (23.8)	[55]
	Dindigul	2004	150	132 (88.0)	18 (12.0)	[55]
	Ramanathapuram	2004	140	126 (90.0)	14 (10.0)	[55]
	Pudukkotai	2004	151	122 (80.8)	29 (18.2)	[55]
	Thanjavur	2004	202	183 (90.6)	19 (9.4)	[55]
	Sivaganga	2004	180	108 (60.0)	72 (40.0)	[55]
	Perambalor	2004	150	133 (88.7)	17 (11.3)	[55]
	Villupuram	2004	181	177 (97.8)	4 (2.2)	[55]
	Trichy	2004	157	110 (70.1)	47 (29.9)	[55]
	Karur	2004	200	138 (69.0)	62 (31.0)	[55]
	Madurai	2004	150	145 (96.6)	5 (3.3)	[55]
	Salem	2004	200	167 (83.5)	33 (16.5)	[55]
	Namakkal	2004	207	145 (70.0)	62 (30.0)	[55]
	Kancheepuram	2004	200	169 (84.5)	31 (15.9)	[55]
	Thiruvannamalai	2004	162	157 (96.9)	5 (3.1)	[55]
	Virudunagar	2004	160	156 (97.5)	4 (2.5)	[55]
	Dharmapuri	2004	100	80 (80.0)	20 (20.0)	[55]
	Vellore	2004	130	113 (87.0)	17 (13.1)	[55]
	Tiruvallore	2004	170	104 (61.2)	26 (38.8)	[55]
	Tiruvarur	2004	150	148 (98.7)	2 (1.3)	[55]
	All districts	2010	1228	583 (47.5)	645 (52.5)	[80]
Tripura	Tripura	2002	1123	375 (33.4)	748 (66.6)	[56]
	Tripura	2004	60	36 (60.0)	24 (40.0)	[16]
Uttarakhand	Uttar Kashi	1998	255	33 (13.0)	222 (87.1)	[16]
	Pauri	1998	224	22 (10.0)	202 (90.1)	[16]
	Pithoragarh	1998	244	40 (16.4)	204 (83.6)	[16]

Contd...

Table 2: *Contd...*

State	Name of the district	Year	Number of salt samples	Iodine content of salt (ppm)		Reference
				<15	15 ppm and more	
	Dehradun	2001	300	58 (19.3)	242 (80.7)	[8]
	Nainital	2003	210	116 (55.2)	94 (44.8)	[15]
	Nainital	2013	642	272 (42.3)	370 (57.7)	[81]
	Udham Singh nagar	2013	660	352 (53.3)	308 (46.7)	[82]
	Pauri	2013	562	335 (59.6)	227 (40.4)	[83]
	Udham Singh nagar	2014	597	297 (49.7)	300 (50.3)	[84]
	Nainital	2014	548	181 (33.0)	367 (67.0)	[84]
	Pauri	2014	349	147 (42.1)	202 (57.9)	[84]
Uttar Pradesh	Lakhimpur Kheri	2001	298	276 (92.6)	22 (7.4)	[8]
	Mainpuri	2001	394	355 (90.1)	39 (9.9)	[8]
	Badaun	2001	797	484 (60.7)	313 (39.3)	[8]
	Saharanpur	2001	290	236 (81.4)	54 (18.6)	[65]
	Meerut	2001	205	140 (68.3)	65 (31.7)	[65]
	Meerut	2001	716	382 (53.4)	334 (46.6)	[65]
	Bareilly	2001	200	164 (82.0)	36 (18.0)	[65]
	Agra	2001	195	113 (57.9)	82 (42.0)	[65]
	Kanpur	2001	200	198 (99.0)	2 (1.0)	[65]
	Lakhimpur	2001	238	230 (96.6)	8 (3.3)	[65]
	Jhansi	2001	855	461 (53.9)	394 (46.0)	[65]
	Mahoba	2001	390	275 (70.5)	115 (29.5)	[65]
	Lalitpur	2001	202	146 (72.3)	56 (27.7)	[65]
	Sidharth nagar	2001	184	126 (68.5)	58 (31.5)	[65]
	Padrona	2001	225	48 (21.3)	177 (78.6)	[65]
	Sultanpur	2001	179	120 (67.1)	59 (32.9)	[65]
	Gorakhpur	2001	212	38 (18.0)	174 (82.1)	[65]
	Varanasi	2001	288	220 (76.4)	68 (23.6)	[65]
	Shahjhanpur	2003	210	203 (96.6)	7 (3.4)	[15]
	Shahranpur	2003	209	154 (73.7)	55 (26.3)	[15]
	Sidharth nagar	2008	175	153 (87.4)	22.0 (12.6)	[85]
	Sidharth nagar	2009	210	174 (82.9)	36 (17.1)	[58]
	Gonda	2010	338	267 (79)	71 (21)	[59]
West Bengal	Darjeeling	2003	210	103 (49.0)	107 (51.0)	[15]
	Jalpaiguri	2003	209	115 (55.0)	94 (45.0)	[15]
	Dakshin Dinajpur	2004	2250	733 (32.6)	1517 (67.4)	[61]
	South 24 Parganas	2005	455	202 (44.4)	253 (55.6)	[60]
	North 24 Parganas	2006	363	109 (30)	254 (70)	[62]
	Purulia	2006	2400	1598 (66.6)	802 (33.4)	[63]
	Howrah	2008	175	53 (30)	122 (70)	[64]
	Medinipur	2008	2400	1191 (45.6)	1209 (54.4)	[86]
	Darjeeling	2014	2400	134 (5.6)	2223 (92.6)	[87]

studies conducted in India reported the incidence of congenital hypothyroidism (CH) as 1:476, 1:1700, 1:2481 and 1:2804, respectively.[95-98]

Nutritional ID and endemic goiter are widely prevalent in developing countries, affecting an estimated 1 billion people. It continues to affect hundreds of millions of people in the developing world, even though simple and effective methods of eradication.

Neonatal Hypothyroidism is the most treatable cause of mental retardation. A pilot neonatal hypothyroid screening program carried out in three areas of India showed that the incidence of NH in severely iodine deficient areas is between 4% and 15%. This is 80–300 times more than the reported average incidence of NH in medically advanced countries, which have eradicated endemic goiter, endemic cretinism and other effects of ID by effective iodine supplementation program.

One of the studies has shown that the incidence of NH as reflected in cord-blood T4 and TSH levels in endemic goiter regions is more than a hundredfold higher than that observed in non-endemic regions of India or reported from developed countries of the West. The reported incidence of NH in endemic regions of India and its neighboring countries ranges from 6 to 130/1000 births.[99]

In early 80s by screening the cord blood of over 20,000 newborns, it was discovered that one out of every 10 newborns from the Tarai regions of UP were hypothyroid at birth. The study was conducted by Kochupillai *et al.* in which they screened newborns from three different regions of India that is, (i) three severely iodine deficient, endemic district of the Gangetic Plains of Uttar Pradesh (Deoria, Gorakhpur and Gonda) (ii) the hospitals of the capital city of Delhi; where a mild degree of EID and endemic goiter are prevalent; and (iii) two coastal districts (Aleppey and Quilon) of the southern state of Kerala. The results showed an incidence of NH as 133, 85 and 75, respectively in the three endemic districts of UP, much higher than in Delhi and in coastal Kerala/1000 births.[100]

The incidence of NH, as reflected in cord-blood thyroxin and thyrotropin levels, varied from 0.6% to 13.3% in iodine deficient and normal regions of India, depending on the degree of EID as assessed by the pattern of urinary iodine excretion in the affected population.[99]

Another study was conducted to reevaluate the incidence of NH in the same three districts of UP in the postiodation phase. The results showed the incidence of NH was 16.17 and 9/1000 birth, respectively, which was impressively declined.[99]

The impact of ID related NH on brain development in non-cretinous population has also been assessed by determining the IQ and the prevalence of nerve deafness among children in the population of severely iodine deficient villages in areas with a very high incidence of NH. The results showed a much higher gross shift to the left of the distribution of IQ scores among primary school children from endemic-goiter villages than in children from non-endemic. The audiometric testing revealed sensory neural hearing loss in one of every five subjects screened from the endemic goiter villages.[99]

One of the studies conducted in Mumbai in which 12,407 neonates were screened over 26 months for their cord blood thyrotrophin level TSH, reveled a higher incidence (1:2481) of NH.[96] Data on NS for NH with cord blood T4 studies on more than 25,000 newborns in the same area of Mumbai have shown the incidence of 1 in 2,804.[97]

Currently, there are no national programs for NH screening in India.[98]

Global scenario

The worldwide incidence of CH is 1:3000–1:4000.[99] The incidence has racial and global topographic differences, being highest in Europe 1:3300 and as low as 1:5700 live births infants in Japan with an average of 1:4500 live births in most other parts of the globe.[100]

Neonatal thyroid screening in the United Kingdom has shown a significantly higher incidence of NH in Asian families in comparison with non-Asians (1/918 in Asians compared 1/3391 within non-Asians).[101] The incidence is lower among African American newborns and higher among Hispanic newborns compared with the rate among white newborns.[102] International studies have revealed that the incidence of NH is approximately 1:3500 in iodine sufficient areas.[103]

Incidence of NH in several countries has been well documented. Earlier studies reported an Incidence of NH as 3:1207 (Ethiopia), 1:1446 (Italy), 1:1667 and 1:3670 (Latin America), and 1:4000 (United States), respectively.[104-107] Newborn screening in Brazil had revealed consistent lowering in the incidence of NH in 3 consecutive years (1:3616 in 2005, 1:1369 in 2006 and 1:1030 in 2007).[108] Thus, this high prevalence of NH is indicative of widespread IDD throughout the globe at different intensities.

The incidence of NH has been reported as 1 in 3,800–4,000 births worldwide with some racial and geographic variations.[109] Based on ongoing screening program, the incidence of NH in developed countries has proved to be high and varies from 1 in 2,000 to 6,000 births.[110] It has also been reported that the incidence of NH in developed countries without ID or endemic goiter varies from 1 in 3,000 to 1 in 12,000 births.[111-113] The worldwide incidence of NH was found to be one in 3000–4000 births, based on the results of screening in parts of the world where screening is mandatory.[99]

Data of an earlier study on NS have showed a prevalence of goitrous hypothyroidism in 10–15% of patients with primary CH approximating 1 in 30,000–50.000 live births in Europe and in North America.[114] One of the studies conducted in the region of Sicily examined the cord blood samples of 180 newborns, and it showed that the prevalence of NH was 9.3% at birth with endemic goiter and cretinism.[115]

High incidences of NH in iodine deficient areas with endemic goiter and/or cretinism have been documented from other countries. Thilly *et al.* reported 10% incidence of NH in Zaire, as reflected in cord blood hormone levels during birth.[116] One of the studies conducted on 20107 newborns in Tehran and Damavand showed the estimated incidence of CH as one in every 914 births.[117] The routine cord blood thyrotrophin TSH screening of neonates at 6–10 days in Birmingham (England), reported the incidence of NH as 1:5540.[118]

One of the studies conducted in Saki (Nigeria), reported the incidence of neonatal chemical hypothyroidism as 14.7/1000 birth in the cord blood samples obtained from the babies at the time of delivery for thyroid function tests.[119] Another study conducted in Bhutan screened 650 newborns for TSH and results showed that the overall incidence of NH among newborns was 115/1000 births.[120]

Need for newborn screening program

Neonatal hypothyroidism screening has been identified as a potential method for early detection and prevention of the adverse effects of thyroid deprivation on the brain development of neonates, thus promoting an early intervention. Worldwide, NS program for NH have significantly reduced the intellectual deficits in the hypothyroid children treated early. Newborn screening and thyroid therapy if started within 2 weeks of age can normalize cognitive development. As hypothyroid fetuses often perish in the womb and many affected infants die within a week of birth.

Newborn screening for NH has been implemented in the United States, Canada, Western Europe, Japan, Australia, New Zealand, Taiwan, parts of China, Mexico and Israel.[121] NH screening programs have been instituted to allow its early detection and initiation of therapy.[105] It resulted in bringing down worldwide incidences of NH from 1:7000 to 1:3000 to 4000.[122] Under this, the newborns are subjected to screen for hypothyroidism by estimation of serum thyrotrophic TSH levels. TSH level of more than 20 μl/dl in neonates indicates insufficient supply of thyroid hormones to the developing brain.

Newborn screening is ultimately a public health program. Successful screening programs results from collaborative efforts of different sectors. If a program is accepted as Government responsibility, advocacy efforts can be broad. These organizations can provide support through established networks. The Government agencies can be asked to include topics related to newborn screening in curricula of health allied services. As in Thailand and Manila, Government funds were helpful in supporting NH programs.

The non-Governmental Organizations (NGOs) can be roped together as academic institutes, insurers, civic organizations, media, religious groups, etc., As, in USA, The Clinical and Laboratory Standard Institute has been active in publishing guidance on procedures related to the collection of neonatal data for standardization of NS.

Counseling of future parents about NS can also be useful. A comprehensive institutionalization of NS program within the public health system is a key step in implementing and sustaining an NS program.[123] The objective of NS programs is the commencement of treatment of affected neonates with hypothyroidism within the first 2 weeks of life. The early detection can improve prognosis and lead to full brain development of the newborn. Screening is not a confirmatory diagnosis, it will require further investigations.

Limitations of neonatal screening program in India

A vicious cycle exists, that prevents the early identification and subsequent management of NH in India. Despite its simplicity, accuracy and cost effectiveness, NH screening as mandatory primary health care activity in India is yet awaited. This could be due to contributing factors such as (i) high home delivery rate, (ii) early discharge from hospitals (iii) cultural taboos related to newborns (iv) lack of reliable laboratories on a large scale, and (v) non-availability of baseline data in our population has added to the challenge. These limitations have reduced the utility of the screening program which otherwise have been estimated to be the best method to trace out neonates affected with hypothyroidism in large populations.

The way forward in India is to prioritize districts identified endemic to ID and implement a compulsory NS program in these areas. The endemic areas can be listed through Hospital based as well as Institution based studies. Apart from this mass education, media propagation and training centers will be required for the smooth implementation and enhanced the efficacy of screening programs. NGOs already stationed in the periphery can be roped in for better execution. In the absence of a national program, organizations like Indian Academy of Pediatricians should bring out guidelines for NH screening and institutions should develop local guidelines for screening all newborn.

Neonatal Hypothyroidism Screening if properly timed and performed has the potential for preventing catastrophic health outcomes, including death.[94] The vast majority of children with NH cannot be diagnosed on the basis of clinical features. The best measure to identify NH is extensive NS. The specimen used for newborn screening tests can be blood collected from umbilical cord or a heel-prick (collected between 2 and 5 days of age) on filter paper. We believe that the cord blood filter paper method for TSH assessment is a viable option for the 'universal screening' of newborns for NH in India.

Conclusion

Thus, the current scenario indicates the presence of ID in the country. We have limited data on the status of IDD among newborns. Hence, there is a need of developing NS program to establish the status of ID in newborn. This would help in early detection of children with IDD/NH.

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