Original Article

An assessment of progress toward universal salt iodization in Rajasthan, India, using iodine nutrition indicators in school-aged children and pregnant women from the same households

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Background: In Rajasthan, an Indian State with significant salt production, the sale of non-iodized salt for human consumption was banned in 1992. This study explored the relationships between the use of iodized salt in Rajasthan and the iodine status of children and pregnant women living in the area. **Methods**: In a State-wide survey, 30 clusters were selected proportionate-to-population-size and 40 school children, 6 -12 years old, were enrolled by random house-to-house visits in each cluster. Twelve pregnant women from the same households were also sampled. Salt used for cooking and a casual urine sample from each child and pregnant woman were collected. The salt iodine content was measured by titration and the urinary iodine concentration (UIC) by a quality-assured colorimetric method. **Results**: Salt iodine content was ≥15mg/kg in 41.9% of the households, and 23.0% used non-iodized salt. Median UIC was 139µg/L in children and 127µg/L in pregnant women. In households using non-iodized salt, the median UIC's were 96µg/L and 100µg/L in children and women, respectively. Disaggregating the UIC distributions by salt iodine levels revealed a consistent, step-wise pattern of UIC in children with increasing salt iodine content. A similar but less steep pattern was observed in pregnant women. The iodine status of both children and pregnant women attained the optimal range only when the salt iodine content was close to 30mg/kg. **Conclusion**: For optimum iodine status in the population of Rajasthan, the iodization of household salt should be mandated at a higher level than what is practiced at present.

Key Words: universal salt iodization, urinary iodine excretion, iodine, ban on non-iodized salt

INTRODUCTION

After the Heads of State and Government at the World Summit for Children in 1990 pledged to pursue the global goal to eliminate Iodine Deficiency Disorders (IDD), significant progress has been made in many countries to reach this goal through the promotion of universal salt iodization (USI), i.e., the iodization of all salt used for human and animal consumption. Almost 70 percent of the 5 billion people living in countries affected by IDD have access to iodized salt at present.[1] Dietary iodine is required by human beings for the biosynthesis of thyroid hormones, which are essential for normal brain development and function. The fetus and newborn infant are particularly vulnerable to the damaging effects of iodine deficiency.[2]

In an attempt to monitor the progress toward IDD elimination through USI, technical expert groups, convened by ICCIDD, WHO and UNICEF, have recommended population indicators which include the percentage of households using adequately iodized salt (≥ 15mg iodine per kg salt) and the urinary iodine concentration (UIC) in a representative sample of the population.[3] Traditionally, the distribution of UIC among school children was used to assess the extent and severity of iodine deficiency. This practice is increasingly extended, also in surveys, and aims to track the progress made in reaching the IDD elimination goal. In view of the higher iodine requirements of pregnant women and the vulnerability to iodine deficiency during the fetal and newborn period, however, the validity of using the UIC distribution in school children for assessing the progress in IDD elimination remains in question.

IDD continues to blemish the health and wellbeing of the population in India.[4] A National Goiter Control

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Program was launched as early as 1962. This was renamed in 1992 as the National IDD Control Program, while adopting USI as the major strategy to reach IDD elimination in all the States. Evidence has accumulated that indicate that IDD is a widespread public health problem in virtually all the States and Union Territories in India[5] and, except in Kerala and Gujarat, the sale of non-iodized salt for human consumption has been banned by all State legislatures. Also in Rajasthan, one of the three major salt producing States of India, the sale of non-iodized salt was banned from the markets in 1992 upon finding evidence of iodine deficiency in the population.

The present study was conducted in Rajasthan to assess the progress being made in IDD elimination through USI, using the internationally recommended indicators for assessing the iodine status of school children. For a comparison of indicators between population subgroups, the survey design also included assessment of the iodine status of pregnant women.

SUBJECTS AND METHODS

A cross-sectional, community-based survey was conducted in 2003, based on a population-proportionate-to-size selection of 30 clusters from the electoral list of all the villages and urban wards in Rajasthan. Except where described, methods recommended by an ICCIDD/WHO/UNICEF expert group[3] were followed. We aimed at attaining a precision of ±5% at 50% prevalence, requiring a sample size of 1,142 at a design effect of 3. Informed consent was obtained from appropriate authorities in the State and from each participating individual.

Trained survey teams enrolled participants from 1,200 households, consisting of 40 households in each cluster chosen in a random staged fashion. Male and female children aged from 6 to 12 years were chosen as the index respondent in random house-to-house visits. If an eligible child was not resident in a selected household, the nearest households were visited until a target child was encountered. When more than one child was found in a given household, only one child was included at random. When a pregnant woman was living in the household with an eligible child, she was also invited to participate. The aim was to include at least 12 pregnant women in each cluster. If not enough pregnant women were enrolled in a given cluster upon completion of 40 households with an eligible child, additional random sampling of households was made from the electoral list until the minimum of 12 pregnant women was accomplished. For each additional household included, the data and sample material of a previous household with only a child enrolled was discarded at random, thus ending up with data of 1,200 households, 360 of which had woman-child pairs.

Salt samples were collected from the salt used for meal preparation in the household on the same or previous day of the survey visit. The salt was packed in an auto-seal polythene pouch and transported to a central collection point in the State. One batch of salt samples was lost in transit. Upon completion of the survey, all salt samples were sent in one shipment to the Indian Coalition for Control of Iodine Deficiency Disorders (ICCIDD) reference laboratory at the Center for Community Medicine (CCM) in the All India Institute of Medical Sciences (AIIMS), New Delhi, where the iodine content was assayed by iodometric titration.[3]

A casual urine sample from each child and each pregnant woman was collected and preserved in wide mouth plastic bottles with screw caps. Urine samples were sent within 24 hours to a central collection point in the State and refrigerated to prevent bacterial growth. All urine samples were transported in one shipment to the ICCIDD reference laboratory in the CCM at AIIMS in New Delhi. Urinary iodine estimation was done using a micropipette method.[6] The laboratory participated in the CDC-organized EQUIP program for external quality control. The urinary iodine assays were completed within established predetermined limits for analytical performance, and a precision of 4.3% was achieved at the bench control concentration of 140µg/L.

Data analysis

Experienced data entry specialists carried out data input into Excel. Data analysis in Excel was enhanced by using Analyse-It plug-in software[7] for distribution analysis and calculation of standard non-parametric statistical estimates, and 95% confidence intervals for proportions and relative risks were calculated with CIA software.[8]

RESULTS

The median iodine content in 1,157 household salt samples was 10.6mg/kg. Only 41.9% of the salt samples contained ≥15mg/kg iodine and the salt iodine content was

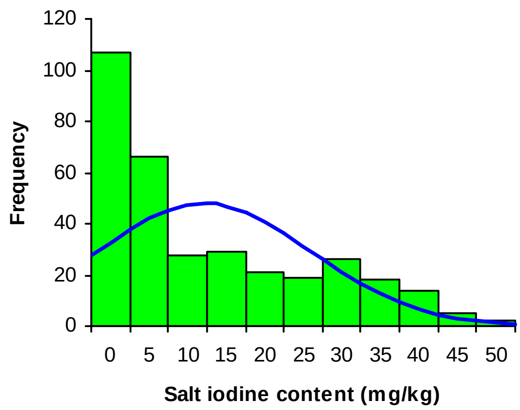

Figure 1. Frequency distribution of iodine content in household salt, Rajasthan, India

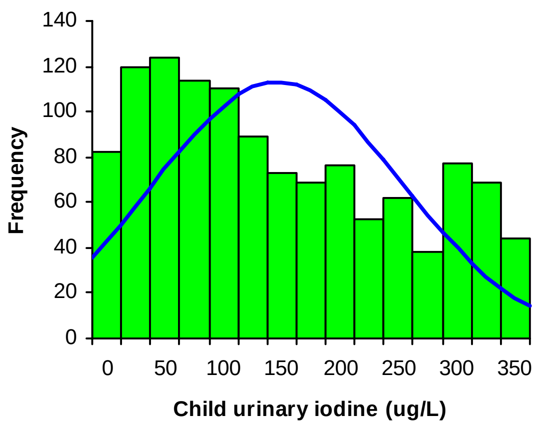

Figure 2. Frequency distribution of urinary iodine concentration in school children, Rajasthan, India

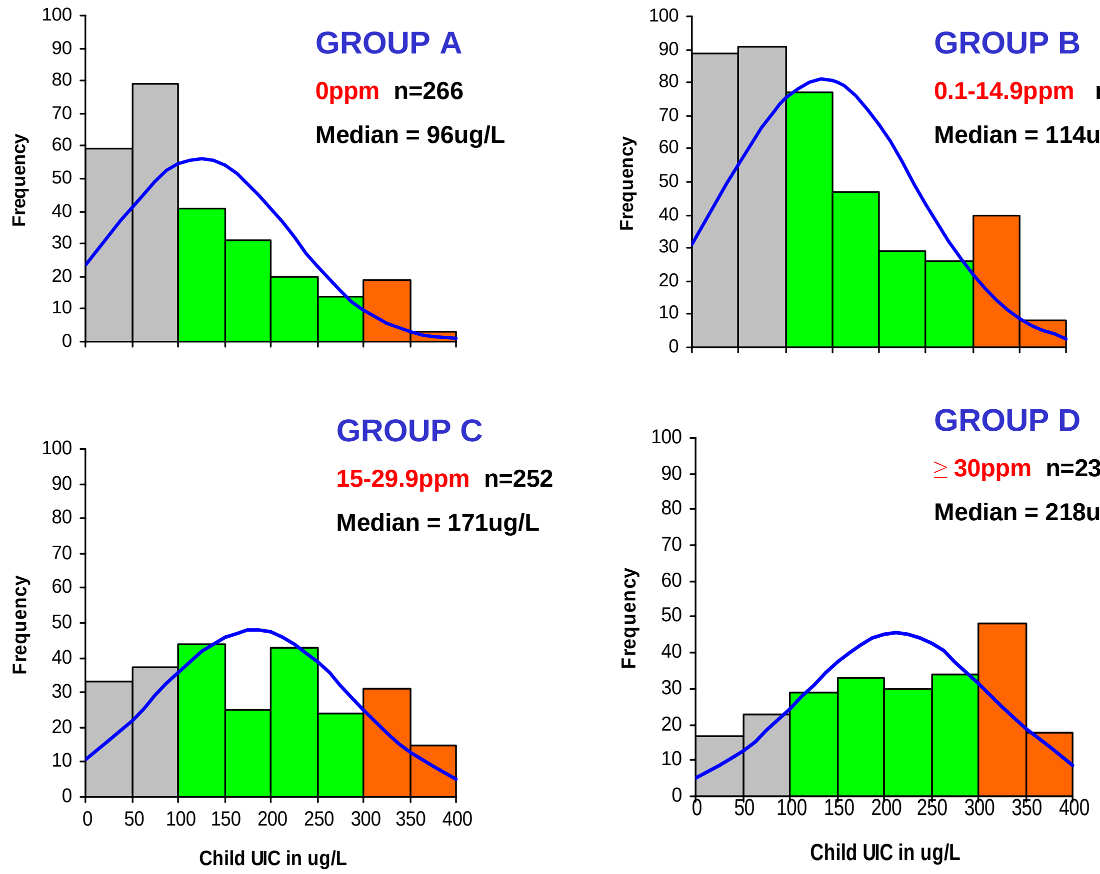

Figure 3. Urinary iodine distribution in school children disaggregated by iodine content in their household's salt, Rajasthan, India

Table 1. Relationship between household salt iodine levels and child urinary iodine concentration

Household salt iodine contents (mg/kg)	Child Urinary Iodine Concentration (µg/L)		
	N	Median and Inter-Quartile Range	95% Confidence Interval of Median
0	266	96; 54 – 182	83 – 113*
0.1 - 14.9	407	114; 57 – 201	103 – 125*
15 - 29.9	252	171; 88 – 263	146 – 209
≥ 30	232	218; 129 – 315	199 – 250*

* $p<0.001$ compared to the group with household salt iodine contents 15-29.9mg/kg

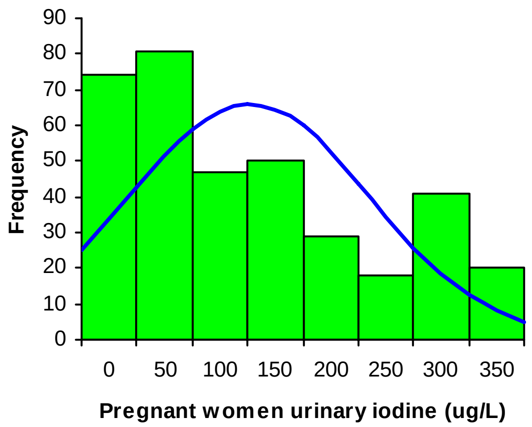

Figure 4. Frequency distribution of urinary iodine concentration in pregnant women, Rajasthan, India

0 mg/kg in 23.0% of the households. The inter-quartile range of salt iodine content (IQR; 25th to 75th percentile) was 4.2 - 25.6mg/kg iodine. Figure 1 shows the household salt iodine frequency distribution and the significant skew toward higher salt iodine contents.

Figure 2 shows the frequency distribution of urinary iodine concentrations of the 1,200 children in the survey, with a median UIC of 139µg/L and IQR 70 - 254µg/L. Because the distribution of the household salt iodine content indicated that the iodine consumption between children was likely to differ, UIC categories were constructed for comparing children from households with salt iodine contents 0mg/kg, 0.1-14.9mg/kg, 15-29.9mg/kg and ≥30mg/kg. The UIC distributions in these 4 groups of children are shown in Figure 3 and Table 1. With the stepwise increases in household salt iodine levels, a shift is observed of the child UIC distributions to a higher urinary iodine level ($p<0.001$). Also, the shape of the child UIC distributions is observed to change with the increase in household salt iodine levels, from a positive skew in children from households using non-iodized salt or salt with low iodine, to the more closely bell-shaped UIC distributions among children from the households with salt iodine ≥15mg/kg. The median UIC was 96µg/L in children from households using non-iodized salt and 218µg/L in children from households using salt with ≥30mg iodine per kg. The median UIC among children in households having salt with 15-29.9mg/kg iodine (Group C) was 171µg/L, which is within the internationally

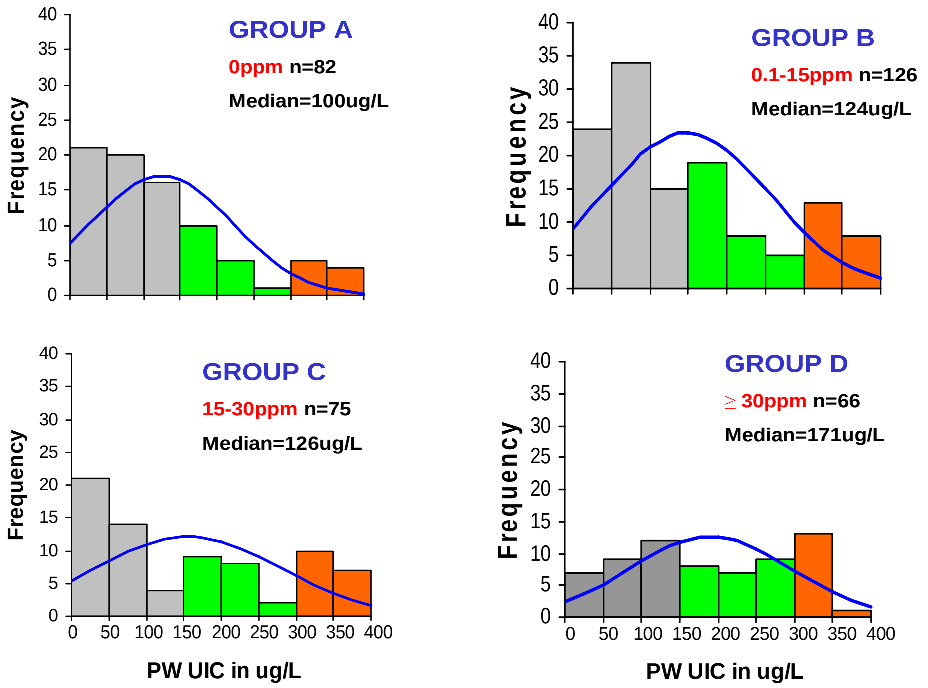

Figure 5. Urinary iodine distribution in pregnant women disaggregated by iodine content in their household's salt, Rajasthan, India

recommended range for urinary iodine excretion for school-aged children.

The median urinary iodine among the 360 pregnant women was 127µg/L, IQR 55 - 230µg/L. Figure 4 shows their UIC frequency distribution. The UIC among 56% of the women was <150µg/L and 27% of the UIC values were in the range of 150-300µg/L. A UIC less than 50µg/L was observed in 20.9% of the women, and 43.3% of the UIC assays were <100µg/L. Figure 5 and Table 2 show the UIC distributions of pregnant women in this survey categorized on basis of the same iodine contents categories in their household salt, as was done for the children. Similar to the children, a shift is observed in the locations and shapes of the UIC distributions in women with the increasing iodine levels in household salt. Since the number of pregnant women is small in comparison to children, however, the differences in their median UIC levels did not reach statistical significance. Only by comparing the UIC distributions in women from households with salt with an iodine content of <15mg and ≥15mg iodine/kg was significance approached. The median UIC among pregnant women from households with salt iodine content of <15mg/kg was 112ug/L and it was 160µg/L among the pregnant women with household salt iodine content of ≥15mg/kg (p=0.06).

Table 2. Relationship between household salt iodine levels and urinary iodine concentrations in pregnant women

Household salt iodine contents (mg/kg)	Urinary Iodine Concentration (µg/L) of pregnant women		
	N	Median and Inter-Quartile Range	95% Confidence Interval of Median
0	82	100; 47 – 163	80 – 118
0.1 - 14.9	126	124; 57 – 208	87 – 150
15 - 29.9	75	126; 47 – 247	74 – 182
≥ 30	66	171; 107 – 271	140 – 235

DISCUSSION

After more than a decade of an official ban on the sale of non-iodized salt in the markets of Rajasthan, the main interest in the present survey was to explore the progress made in the effort to reach USI. Only 41.9% of the households were observed to be using salt with iodine contents of ≥15mg/kg, a finding that clearly falls short of the agreed-upon target. Nevertheless, the median UIC of 139µg/L in school-aged children fell in the recommended range[3] for adequate iodine status, which would potentially lead to the conclusion that iodine deficiency in the population of Rajasthan had become a matter of the past. The analysis of the UIC frequency distribution in children, when grouped by the iodine contents in their household's salt, demonstrates that this would have been an incorrect inference.

The strength of this study was that the salt samples were obtained from the same households where the children and pregnant women were enrolled. This permitted an analysis of the relationships between the consumption of iodized salt, approximated by the salt iodine content in the households, and the iodine status of the population, which in this study is reflected by the urinary iodine concentrations in children and pregnant women living in these households. The findings of a sizable proportion of households using salt without any added iodine, as well as a wide range of iodine contents in the salt used in the remaining households suggested that the iodine consumption differed significantly among individuals. The disaggregated analysis of these relationships by constructing categories of increasing iodine levels in household salt

Table 3. Relative Risks of low (<100µg/L) and high (>300µg/L) urinary iodine concentrations among children related to the iodine contents in their household's salt

Household salt iodine contents (mg/kg)	N	Child Urinary Iodine Concentration (µg/L)			
		Below 100 µg/L		Above 300µg/L	
		%	Relative Risk and 95% Confidence Interval	%	Relative Risk and 95% Confidence Interval
0	266	52	1.87 (1.48–2.35)	8	0.45 (0.28–0.73)
0.1 - 14.9	407	44	1.59 (1.27–2.00)	12	0.65 (0.45–0.94)
15 - 29.9	252	28	1.00	18	1.00
>= 30	232	18	0.65 (0.46–0.91)	28	1.55 (1.11–2.15)

clearly illustrated that the UIC distributions in the children and pregnant women were not from a single homogeneous population, but constituted of different population sub-groups, including a major category of households in which the progress toward adequate iodine status was significantly lagging behind, in association with their use of non-iodized salt.

The importance of appropriate iodine content in household salt becomes all the more apparent by estimating the relative risks of low (<100µg/L) and high (>300µg/L) child UIC in each salt iodine category, as compared to the children from households using salt with 15-29.9mg/kg iodine (Table 3). Significant stepwise changes ($p<0.01$) are apparent in the relative risks at each side of the UIC frequency distribution, indicating the significant responsiveness of the urinary iodine excretion in school-aged children to their iodine consumption from household salt. With each 10mg/kg increase in salt iodine content, the UIC among the school-aged children in Rajasthan increased by approx. 30-35µg/L.

The study encompassed 360 pregnant women from the same households where the children were also enrolled. Similarly to children, a stepwise increase in urinary iodine concentration with increasing iodine contents in household salt was observed in pregnant women, although the differences between the groups did not reach statistical significance. This was partly because of the smaller sample size. In households using non-iodized salt, the median UIC in pregnant women was 100µg/L, significantly below the desired minimum for pregnant women of 150µg/L.[9 (WHO, in preparation)] In households with salt iodine contents ≥30mg/kg, the median UIC among pregnant women was 171µg/L. The two intermediate salt iodine categories had very similar median urinary iodine levels among the pregnant women at 125µg/L. Therefore, it would appear that among the pregnant women in this study, the responsiveness in urinary iodine concentrations to variations in the iodine content of their household's salt is sizably smaller than in school-aged children. Each 10mg/kg change in salt iodine content was associated with a change in UIC of approx. 15-20µg/L in the pregnant women, about half of that found in the school children.

The dietary iodine intake requirements in a population are closely related to the age and sex-specific group, and pregnant women need additional iodine due to their physiological state.[10] The availability of commercial foods manufactured with iodized salt as part of the recipe is limited in Rajasthan and, therefore, the assurance of an optimum iodine supply in the population through salt iodization depends mostly on the iodine content and the amount of salt used in the households. This study indicated that the iodine status in children from households using salt with 15-29.9mg/kg was within their recommended optimal range, while at the same time, the iodine status in pregnant women living in the same households fell below the desired minimum level. Only when the iodine content in household salt arrived at or near 30mg/kg were both the UIC distributions in children and pregnant women showing levels considered adequate for their groups.

Rationally, the foremost priority for addressing the dietary iodine shortfall in the population of Rajasthan would be to enforce the existing ban on the sale of non-iodized salt in the markets. Removing the households using non-iodized salt from the present database raised the median UIC in pregnant women from 127 to 138µg/L, a sizable improvement but still remaining below the desired minimum and therefore suggesting the need to not only intensify the efforts to reach USI, but also to increase the salt iodization level. The results of this survey illustrate the difficulty of achieving optimum iodine status among all groups in a population when household salt is the single source of additional dietary iodine.

In summary, the results of a population-representative survey in Rajasthan, an Indian State with significant and widespread local salt production, demonstrated the significant shortfall in reaching the USI goal after more than a decade of an official ban on the sale of non-iodized salt. Although the overall urinary iodine excretion among school-aged children suggested that the pre-existing iodine deficiency in the population had been eliminated, UIC distribution analysis disaggregated by the salt iodine contents in households demonstrated that optimum iodine nutrition had not been assured in almost one-third of the population. By also sampling pregnant women in the same households where eligible children were enrolled, it was possible to compare the outcomes of the State's USI status in each population sub-group. The comparison indicates that in a situation, such as in the Indian State of Rajasthan, where very few households consume foods industrially processed with iodized salt, reliance on an assessment of the UIC distribution in school-aged children only may be grossly misleading. Ensuring optimum iodine status in the population is not simple and straightforward under these circumstances. The present results in Rajasthan indicate the need for not only a more effective effort to reach USI but also a modest increase in the mandated salt iodization level.

AUTHOR DISCLOSURES
Eric-Alain Ategbo, Rajan Sankar, Werner Schultink, Frits van der Haar and Chandrakant S Pandav, no conflicts of interest.

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以碘營養指標評估印度拉賈斯坦邦同一家戶的學童與孕婦全面食鹽加碘的進展

背景：拉賈斯坦邦為印度重要的食鹽出產地，在 1992 年開始被禁止販售未加碘食鹽給人食用。本研究探討在拉賈斯坦邦使用加碘食鹽與居住此地區孩童及孕婦的碘狀態之相關性。方法：拉賈斯坦邦全州的調查，依族群大小比例選取 30 個叢集，並從每個叢集中隨機到府拜訪選取 40 名 6-12 歲的孩童。12 名孕婦也選自相同的家戶。收集家戶中使用的烹調用鹽及每名孩童及孕婦的任一時間尿液樣本。使用滴定法及品質保證比色法分別測量鹽中碘含量及尿中碘濃度(UIC)。結果：有 41.9%的家庭鹽碘含量≥15mg/kg，23%使用未加碘食鹽。孩童的 UIC 中位數為 139μg/L，孕婦為 127μg/L。在使用未加碘食鹽的家戶中，孩童及孕婦的 UIC 中位數分別為 96μg/L 及 100μg/L。UIC 的分佈情形顯示隨著鹽碘含量增加與孩童的 UIC 是呈現一致的逐步模式。孕婦的狀況類似，但較為緩和。孩童及懷孕婦女碘的狀態只有當鹽碘含量接近 30mg/kg 時，才能達到理想的範圍。結論：為使 Rajasthan 的人民能達到理想的碘狀態，應該實施在家戶中的食鹽加比目前更高的碘。

關鍵字：全面食鹽加碘、尿液碘排泄、碘、禁止未加碘食鹽。