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Remaining challenges in Tanzania's efforts to eliminate iodine deficiency

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Abstract

Objective: To determine iodine levels in salt and iodine deficiency prevalence in school-aged children in 16 districts in Tanzania with previous severe iodine deficiency.
Design: A cross-sectional study in schoolchildren. Systematic probability sampling was used to select schools and subjects for goitre assessment and urinary iodine determination.
Setting: Sixteen districts randomly selected from the 27 categorised as severely iodine-deficient in Tanzania.
Subjects: The study population was primary-school children aged 6–18 years who were examined for goitre prevalence and urinary iodine concentration (UIC). Salt samples from schoolchildren's homes and from shops were tested for iodine content.
Results: The study revealed that 83.3% of households ($n = 21\,160$) in the surveyed districts used iodised salt. Also, 94% of sampled shops ($n = 397$) sold iodised salt, with a median iodine level of 37.0 ppm (range 4.2–240 ppm). Median UIC in 2089 schoolchildren was 235.0 $\mu g\,l^{-1}$ and 9.3% had UIC values below 50 $\mu g\,l^{-1}$. The overall unweighted mean visible and total goitre prevalence was 6.7% and 24.3%, respectively ($n = 16\,222$). The age group 6–12 years had the lowest goitre prevalence (3.6% visible and 18.0% total goitre, $n = 7147$). The total goitre prevalence had decreased significantly in all districts from an unweighted mean of 65.4% in the 1980s to 24.3% in 1999 ($P < 0.05$). We believe this difference was also biologically significant.
Conclusion: These findings indicate that iodine deficiency is largely eliminated in the 16 districts categorised as severely iodine-deficient in Tanzania, and that the iodine content of salt purchased from shops is highly variable.

Keywords
Goitre prevention and control
Urinary iodine deficiency
Iodised oil
Iodised salt
Tanzania

Iodine deficiency is the leading cause of preventable mental retardation. It is estimated that globally 1.6 billion people are at risk of iodine-deficiency disorders (IDD), 760 million people have goitre, 43 million suffer from brain damage and 11 million have overt cretinism[1]. Yet iodine deficiency is fully preventable through supplementation or fortification, usually of salt.

In Tanzania, the presence of IDD was recognised in 1963[2], and between 1980 and 1990 a series of district goitre surveys was conducted to establish the magnitude of the problem. These surveys revealed that an estimated 41% of the population lived in iodine-deficient areas and were therefore at risk, while 25% suffered from IDD. This included an estimated 5.6 million people with goitre, 450 000 cretinoids and 160 000 cretins[3]. In the mid 1980s Tanzania began to distribute iodised oil capsules (IOCs) in severely deficient districts as an interim measure, and simultaneously initiated the process of universal iodisation of salt as the permanent strategy, aiming to eliminate IDD by the year 2000[4].

Starting in 1986 IOCs were distributed to the 27 districts most severely affected by IDD, i.e. those with a median urinary iodine concentration (UIC) $\leq 20\,\mu g\,l^{-1}$, visible goitre (3 + 2 + 1b) prevalence $\geq 10\%$ or total goitre prevalence $\geq 30\%$[4]. By 1998, more than 16 million capsules had been distributed to everyone possible aged 1–45 years in eligible districts. The mean coverage of 57 rounds of IOC distribution campaigns in the 27 districts from 1986 to 1994 was 64% (range 24–96%). Capsule distribution was gradually phased out completely in 1996[5] as salt iodisation was satisfactorily established in each district.

The United Nations Children's Fund (UNICEF) spearheaded the procurement and installation of iodation

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machines of varying iodation capacities ranging from 0.5 to 16 tons per hour. Other inputs supported were potassium iodate, packaging materials and test kits for monitoring salt at production, distribution and consumption levels[4]. A process monitoring system for iodised salt was established from household to national levels. By early 1999, an average of 68% of rural households and 87% of urban households in mainland Tanzania had access to iodised salt[6].

The present cross-sectional study was carried out in 1999 in populations living in known IDD-endemic districts. The objective was to determine the iodine status of the previous severely iodine-deficient population.

Methods

Study areas, population and sampling

The present study was conducted in 16 out of the 27 districts that were identified previously as the most severe IDD-endemic districts[4]. These districts are located in nine of the 21 administrative regions of Tanzania mainland. For all regions in which only one district was severely affected, the district was chosen directly for the survey. In regions with more than one affected district, all districts were listed and two or three districts per region were randomly selected by a lottery procedure. Selection of schools within a district was based on three geographical strata, i.e. highland, lowland and township, a criterion that was also used in the baseline survey[3]. Ten schools in each district, i.e. four from highland, four in lowland and two in a township, were selected. A total of 160 schools were selected. However, nine schools (all in different districts and three in each of the geographical strata) could not be reached because of bad roads and heavy rains, and were excluded from the survey.

The study population was primary-school children aged 6–18 years who attended school on the day of the survey. Schoolchildren are commonly used for goitre surveys because of their easy accessibility and their relative suitability in representing the population as a whole[1].

Salt samples for iodine content

Salt samples for iodine analysis were collected from households and in retail/wholesale shops. One child from every household brought a teaspoonful of salt wrapped in a dry paper, which was tested for iodine content using a rapid field-test kit (MBI KITS). This is a semi-quantitative method which can detect ≥ 15 ppm of iodine in salt.

Similarly, a convenience sample of salt brands from shops in the surveyed area was also tested for iodine. Among the salt samples from the shops that tested positive for iodine using the test kit, a convenience sub-sample of five to 10 samples per district was collected for validation of iodine content using the titration method, which has a lower detection threshold of <1.0 ppm iodine and precision (coefficient of variation, CV) of $<15\%$[7].

UIC

For determination of UIC, a sub-sample of 15 children per school was selected through systematic sampling (after palpation of goitre) to give a urine sample[1]. On average 150 urine samples were collected per district, and each child gave 10–15 ml of urine in a 20 ml tightly closed glass bottle. Analysis was done at the Tanzania Food and Nutrition Centre (TFNC) laboratories using the ammonium persulfate digestion method[8]. The accuracy of the assay method was measured using reference quality control specimens supplied by the Centers for Disease Control and Prevention (CDC); it reached a precision of CV $<8\%$, meeting the Division of Laboratory Sciences–CDC's desirable threshold of CV $<10\%$[9,10].

Goitre prevalence

Children aged 6–18 years from 151 schools covered were selected using a systematic sampling procedure with all classes proportionately represented. In each school 120 children were sampled for goitre assessment, making an expected grand total of 18 120 children. However, due to poor attendance in some schools, only 16 222 schoolchildren or 89.5% of the expected sample size was achieved. The 1960 criteria for goitre classification of the World Health Organization (WHO)[11] were used to allow comparison with goitre results obtained in the 1980s by the same method[3], for reasons previously reported[12]. Goitres were graded as 0, 1a, 1b, 2 or 3 by two experienced staff who trained on the goitre palpation and grading procedure according to Perez *et al.*[11].

Ethics and consent

The study proposal was approved by the TFNC's Committee on Research and Ethics. Two of the authors participated in executing the study, where they explained the purpose and requirements of the study to the schoolchildren, primary-school teachers and community members. Only those children who gave verbal informed consent participated in the study.

Data processing and analysis

Data were entered into Epi-Info version 6.02 (CDC/WHO). Entries were validated through running of frequencies and cross-tabulations, and errors rectified against original data forms. Data analysis was done using SPSS version 9.0 (SPSS Inc.) to generate frequencies and proportions for categorical data, and means and medians for continuous data. The non-parametric Mann–Whitney *U*-test was used to compare goitre prevalences in the 1980s with those in 1999. Goitre grades were summed up and categorised as visible goitre prevalence (grades $2 + 3/n$) and total goitre prevalence (grades $1a + 1b + 2 + 3/n$). *P*-values below 0.05 were considered statistically significant.

Results

Use of iodised salt

Sixty-three per cent of household salt samples provided by the schoolchildren ($n = 21\,160$) were crushed/fine. The crushed/fine salt found in most shops was packaged in 500–1000 g plastic packets, while raw coarse salt in 50 kg burlap bags was sold loose from open containers at retail shops and in markets.

Out of 21 160 household salt samples, 83% tested positive, indicating that they had ≥15 ppm of iodine. In seven out of the 16 districts >90% of the household salt samples were iodised, indicating adequacy[1], while the proportion of iodised salt in the household samples from the remaining nine districts ranged from 53 to 83% (Table 1).

In wholesale/retail shops, 94% of the 397 salt samples tested using test kits had iodine ≥15 ppm. This proportion would be considered adequate according to the WHO criterion for iodised salt sold in shops at district level[1].

The median iodine concentration by titration from a sub-sample of 146 out of 397 salt samples in shops, previously tested using test kits, was 37.0 ppm (range 4.2–240 ppm) and mean was 46.1 ppm iodine. Nearly half of the samples were in the acceptable range (Table 2). In 49% of samples, iodine was below the government recommended level of 37.5 ppm[14]. Only 4.8% had excessive levels (>100 ppm iodine).

UIC

Table 1 shows UIC values in 2089 urine samples collected and analysed from primary-school children in 16 districts. The overall median UIC value of $235\,\mu g\,l^{-1}$ indicates adequate iodine intake (median IUC $\geq 100\,\mu g\,l^{-1}$ is recommended by WHO for adequacy). However, four districts had low-to-borderline median UIC values: Songea rural ($88\,\mu g\,l^{-1}$), Ludewa ($92\,\mu g\,l^{-1}$), Mufindi ($92\,\mu g\,l^{-1}$) and Ulanga ($70\,\mu g\,l^{-1}$).

Among the sampled individuals only 9.3% had UIC $<50\,\mu g\,l^{-1}$; this is far below the 20% cut-off point required by WHO for declaring IDD elimination[1]. Meanwhile, 32.2% and 24.0% of the individuals had UIC of 200–500 $\mu g\,l^{-1}$ and $>500\,\mu g\,l^{-1}$, respectively (Table 3).

Prevalence of goitre

Figure 1 compares total goitre prevalence between the baseline goitre surveys in the 1980s and the present survey in 1999 for the 16 districts. The unweighted mean total goitre prevalence in the 16 districts was 24.3%, range 4.1–49.4% (Table 1). These results indicate a statistically significant decrease compared with the unweighted total goitre prevalence in the 1980s of 65.4% (Fig. 1, $P < 0.05$). Such a large difference is also certainly of biological and public health significance.

The total goitre prevalence was 18.0% in children aged 6–12 years ($n = 7147$), 28.3% in 13–15-year-olds ($n = 7041$) and 26.7% in 16–18-year-olds ($n = 2034$). Visible goitre alone was <10% in all age groups (range 3.6–8.6%), with an unweighted mean of 6.7%, compared with 11% in the baseline studies[4], representing a statistically significant decrease ($P < 0.05$) in visible goitre prevalence.

Discussion

This study suggests that iodine prophylaxis consistently pursued from the mid 1980s to 1999 improved iodine

Table 1 Proportion of households and shops found with ≥15 ppm iodine in salt, median urinary iodine concentration (UIC) and prevalence of goitre in schoolchildren by district

District	Salt samples with iodine ≥ 15 ppm at household level		Salt samples with iodine ≥ 15 ppm from shops		Median UIC in schoolchildren		Goitre prevalence in schoolchildren (%)		
	n	%	n	%	n	UIC ($\mu g\,l^{-1}$)	n	VG	TG
Arumeru	2453	92.4	27	96.3	168	327.8	1305	6.6	34.7
Rombo	1605	97.2	45	100.0	114	452.0	1298	0.7	14.9
Mpwapwa	1039	62.1	23	78.3	55	173.2	1285	0.7	6.4
Ulanga	494	61.9	34	85.3	67	69.8	909	0.0	12.4
Mbeya rural	1603	97.8	31	96.8	149	425.4	969	17.9	46.5
Kyela	1439	92.7	16	100.0	149	416.0	1027	0.3	4.1
Mbozi	2374	91.2	15	93.3	149	339.0	1230	1.5	10.2
Mufindi	1261	77.8	21	95.2	150	92.4	989	8.3	23.1
Ludewa	705	76.3	19	78.9	148	92.0	862	8.6	29.0
Songea rural	1384	70.5	7	100.0	149	88.0	993	6.4	23.7
Sumbawanga	1102	64.3	10	100.0	74	194.0	480	1.0	9.6
Mpanda	1111	52.9	19	94.7	165	350.0	1228	1.3	9.0
Biharamulo	1080	83.1	17	82.4	141	126.0	966	7.2	34.3
Ngara	723	94.2	29	96.6	134	395.0	799	17.6	49.4
Kibondo	1030	96.8	33	100.0	136	283.0	910	14.2	41.0
Kigoma	1757	80.4	51	96.1	141	266.0	972	14.2	40.3
Total	21 160	83.3	397	93.7	2089	235.0	16 222	6.7	24.3

VG – visible goitre (grades 2 + 3), in this survey no goitre grade 3 was found; TG – total goitre (1a + 1b + VG).

Table 2 Distribution of titrated iodine levels in salt samples from shops by category

Range of iodine levels (ppm)	Salt samples analysed by titration ($N = 146$) *n*	%	Public health significance[13]
>100.0	7	4.8	Over-iodation
37.5–100.0	68	46.6	Acceptable
18.0–37.4	26	17.8	Low
<18.0	45	30.8	Unacceptable

status, probably by preventing the consequences of iodine deficiency in severely goitre-endemic districts in Tanzania[1,4]. The availability of iodised salt at household level increased dramatically and this decreased goitre prevalence, similar to findings reported in other areas[15–17]. This concurs with the recommendation that salt is the ideal vehicle to deliver iodine to all individuals irrespective of socio-economic status[18,19]. However, several challenges remain before Tanzania can completely eliminate IDD.

Availability of iodised salt

The salt regulations in Tanzania require that all salt meant for human consumption be iodated at 75–100 ppm at factory level and should not contain <37.5 ppm iodine at its point of sale[14]. The presence of salt regulations linked to relevant interventions appears to have worked for Tanzania, but the proportion of households in goitre-endemic districts with access to iodised salt (83%) still falls short of the 90% criterion of adequacy recommended by WHO[1]. Salt with an iodine level of 10 to <15 ppm may not be detected by the test kits, but if available constantly it will likely prevent occurrence of goitre in the absence of goitrogens.

Although the median and mean iodine content at retail level (37.0 and 46.1 ppm, respectively) was close to complying with Tanzanian standards, the range was wide (4.2–240 ppm) and half the retail samples did not comply. This could be due to inadequate salt iodation, poor handling and storage during transportation, or marketing processes before consumption. The uncontrolled traditional iodation technologies used in some salt production sites is likely to lead to a lack of homogeneity in salt–iodine mixing[13]. Some of the salt iodation and storage processes probably are inadequate to control iodine losses. This suggests that there is a need to improve iodation and salt storage procedures and to strengthen internal quality assurance[13,20].

Currently, levels of iodine in salt at household level are on average too low. Yet mean UIC is too high in some districts. One way to deal with these discrepancies would be to improve homogeneity during salt iodation. Continued surveillance is required, as increased use of consumer packaging could eventually require a downward revision of national recommendations for salt iodation levels at production level[14]. Risks of iodine-induced thyrotoxicosis may be substantial in some population groups[21], and this has received only cursory research attention in Tanzania[4].

Table 3 Urinary iodine concentration (UIC) by category in children living in goitre-endemic districts in Tanzania

UIC by category (μg l^{-1})	Frequency ($N = 2089$) *n*	%
<20 (severe)	28	1.3
20–49 (moderate)	167	8.0
50–99 (mild)	291	13.9
100–199 (optimal)	430	20.6
200–500 (excessive)	672	32.2
>500 (seriously excessive)	501	24.0

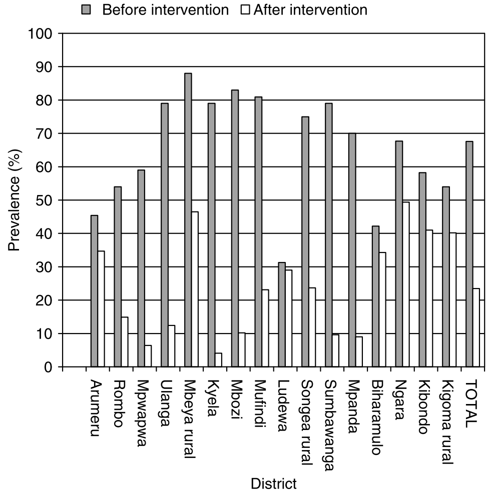

Fig. 1 Total goitre prevalence before (1980s) and after intervention (1999) in 16 high-prevalence districts in Tanzania

Urinary iodine

Urinary iodine is considered the most reliable indicator for IDD assessment in populations. The intake of iodine in a population is considered adequate when the median value of UIC is between 100 and 200 μg l^{-1}, with not more than 20% of the samples below 50 μg l^{-1} (references 1 and 22), which is the criterion met in the districts sampled.

However, 24.0% of children actually had median UIC >500 μg l^{-1} (Table 3). Urinary iodine >500 μg l^{-1} is regarded as a serious excessive iodine intake, since it has been associated with increased thyroid volume which reflects the adverse effects of excess iodine[23]. This emerging problem of serious excessive iodine intake observed in Tanzania was also recently reported in Lesotho[24].

Four districts with median UIC values $< 100\,\mu g\,l^{-1}$ had salt supplied primarily by small-scale producers along the south-eastern coast and central regions of Tanzania, and quality control at the point of iodation for the multitude of small-scale salt producers is inadequate[4]. This suggests that there is a need to have periodic surveys of salt and UIC to monitor actual iodine intake, which then should be adjusted accordingly to ensure a steady median UIC at $100-200\,\mu g\,l^{-1}$ and low proportions below $50\,\mu g\,l^{-1}$.

Ulanga is one of the few districts that had successful coverage of IOC distribution[4] followed by high coverage of availability of iodised salt at household level in the mid 1990s. Sustainable elimination of iodine deficiency needs continuous surveillance to avoid the recurrence of mild iodine deficiency, as recently reported in Tasmania and Morocco[25,26].

Goitre prevalence

After more than a decade of intervention, findings in this study showed that the magnitude of the IDD problem in Tanzania has declined from severe to moderate rate according to WHO standards[1–4]. Apparent goitre prevalence has decreased substantially but still remains high in nine districts (Table 1 and Fig. 1). Ludewa district, with the mildest problem at the baseline survey, showed the least improvement.

There was also little reduction of goitre prevalence in the western districts of Biharamulo, Ngara, Kibondo and Kigoma. This could be due to poor availability of iodised salt from the local large-scale Uvinza salt factory after it was closed for a long period. Also, there has been an influx of refugees into western Tanzania from neighbouring countries where iodine interventions have been hindered by long ethnic wars (Burundi, Democratic Republic of Congo and Rwanda). In Tanzania these refugees received iodised salt whether or not they integrated into local communities, but it will take time for the goitres to regress[27]. That this salt is now adequately iodated is indicated by the high UIC values in these districts.

Goitre regression may be delayed in some districts due to low coverage of the IOC supplementation implemented earlier[5]. In other cases IOC distribution may have ended before iodised salt was adequately supplied and consistently available.

Goitre prevalence varied with age; the youngest children, 6–12 years old, had the lowest prevalence. This is likely, in part, a cohort effect and has been found in similar studies in Tiberina valley in Italy[28] and Lesotho[29]. These younger children were born during the period when IOCs were being widely distributed in these districts[5]. From 1990, salt iodisation gradually started in Tanzania and by 1999 iodised salt was reaching about 77% of the population[6], protecting the younger age group against IDD[30,31]. Thyroid size in older children exposed to iodine deficiency in the first years of life might fail to regress completely following consumption of iodised salt, as observed in previous studies[32,33]. This suggests that goitre prevalence may not be the most appropriate indicator to use in short-term evaluations[33].

The impact (total goitre prevalence declined from 65.4% in the 1980s to 24.3% in 1999) observed in this study is smaller than was seen in Jixian, China, where it was claimed to fall from 65% to 4% only four years after introduction of iodised salt[32]. If the results from the four western districts (described above) are left out, the unweighted mean goitre prevalence for the other 12 districts declined from 68.3% to 18.6%. However, while goitre remains in many areas, we are encouraged by the high urinary iodine levels.

The current iodine status in the vast areas of Tanzania with moderate, mild or no iodine deficiency is not known. Nationwide investigations could assess possible over-iodation and its effects in these areas. There may also be small isolated areas of severity not yet adequately reached by iodised salt. This study reflects the situation in schoolchildren, but other vulnerable groups such as pregnant women and neonates are critical and should also be carefully studied before declaring national elimination of iodine deficiency[34].

We were unable to survey nine out of the 160 schools selected to be in the second survey. As is the case for any survey repeated after such a long period of time in such a low-income setting, there are methodological problems limiting the accuracy of the findings. Goitre palpation always involves substantial intra- and interpersonal variation among examiners[12]. This study benefited from the fact that much of the palpation was done by the same individuals in both surveys, all of whom were highly skilled and experienced.

The results indicate substantive success in controlling a major public health problem in some of the areas worst affected by IDD in a very low-income country like Tanzania. The district differences we found suggest that the approach of doing national-level studies, as reported by Andersson *et al.*[35], may conceal continued iodine deficiency in large segments of the population.

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critical review of the manuscript before submission. T.G. provided intellectual input and contributed to writing the manuscript. S.P. contributed to the study design and provided intellectual input in writing the manuscript.

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