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Evaluation of Iodine Status Among 6–12-Year-Old Children and Iodized Salt Quality in Khogiani District, Afghanistan

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ABSTRACT

Despite reports from the World Health Organization (WHO) highlighting iodine deficiency in various regions of Afghanistan, empirical data for the Khogiani district remain scarce, despite clinical signs suggesting its presence. "This study aimed to assess the prevalence of iodine deficiency among children aged 6–12 years and to evaluate the quality of iodized edible salt in the Khogiani District" A cross-sectional community-based and experimental design was employed. Urinary iodine concentration (UIC) was measured using the Sandell-Kolthoff reaction (spectrophotometric method), while iodine levels in salt samples were determined via iodometric titration. The sample size was calculated using the Cochrane formula, and data were analyzed using descriptive and inferential statistics. Participants were selected via convenience sampling. The overall prevalence of iodine deficiency (UIC: 50–99 µg/L) was 13%, with 1.8% of children exhibiting palpable goiter (grades 1–2). The highest deficiency rates were observed in Wazir and Pirakhel villages. Additionally, 75.1% of salt samples had inadequate iodine content (<15 ppm), with powdered salt being particularly unreliable. Mild iodine deficiency persists among children in Khogiani, and a significant proportion of iodized salt fails to meet the required standards. Public health interventions should prioritize stricter salt iodization monitoring and alternative strategies to ensure adequate iodine intake.

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INTRODUCTION

Iodine deficiency remains a significant yet preventable global health challenge, particularly in resource-limited settings where access to iodine-rich foods is constrained (Kamilla et al., 2022). This essential micronutrient is crucial for thyroid hormone synthesis, metabolic regulation, and cognitive development, with a daily intake of 100–150 µg necessary for physiological function (Dah and L., 2012; Subhan et al., 2015; Aydın et al., 1993). Nearly two billion people worldwide are affected, leading to preventable disorders that disproportionately impact vulnerable groups such as pregnant women and children (Urmatova et al., 2021; Korobitsyna et al., 2020).

The situation in Afghanistan is particularly severe. Approximately 29.5% of children aged 7-12 years show evidence of iodine deficiency, with endemic cases concentrated in mountainous regions like Panjshir, Kapisa, and Parwan (National Public Nutrition Policy and Strategy, 2015-2020; Oberlin et al., 2006; Fahim et al., 2023; Chung et al., 2019). The consequences are dire; UNICEF (2003) estimates that 500,000 Afghan newborns annually face cognitive impairments due to maternal iodine deficiency, creating an intergenerational cycle of reduced potential that hampers national development (Poyesh et al., 2015).

Assessment methods underscore the crisis severity. Breast milk is a key biomarker for lactating women, while urinary iodine concentration (UIC) is the gold standard for population-level assessment (Liu et al., 2022; Urmatova et al., 2021). Empirical evidence consistently links UIC levels below 100 μg/L with a higher prevalence of thyroid dysfunction and nodule formation (Sun & Wang, 2020). This correlation highlights a critical public health issue and underscores the need for effective interventions.

Universal Salt Iodization (USI) has proven to be the most effective and scalable strategy, as demonstrated by the success of China's program (Sun et al., 2017). However, Afghanistan's salt iodization policy, established in 2013, has been undermined by inconsistent implementation and poor enforcement (UNICEF, 2013; Vithanage, 2016). This failure poses a significant risk, given the severe developmental impacts of iodine deficiency on children aged 6–12 years, a consequence evident in diverse contexts, such as India and Norway (Gururaj et al., 2020; McDonald et al., 2022; Oberlin et al., 2006; Subhan & Rizvi, 2015).

The Khogiani district of Nangarhar Province represents a critical knowledge gap. While iodine deficiency in northern Afghanistan is well-documented by the WHO, emerging evidence suggests similar challenges in Khogiani, yet no comprehensive studies have assessed its prevalence or contributing factors (Oberlin et al., 2006). This absence of data hinders the development of targeted interventions and the evaluation of existing programs.

This study addresses these gaps with three objectives: first, to assess iodine deficiency prevalence among school-aged children (6-12 years) using UIC measurements (Urmatova et al., 2021; Eriksson et al., 2023); second, to evaluate household coverage and adequacy of iodized salt against national standards (Mirete et al., 2023; Vithanage, 2016); and third, to identify local barriers to adequate iodine nutrition, including dietary practices, economic constraints, and knowledge gaps. Using rigorous biochemical analysis and household surveys, the research will generate the first comprehensive dataset on iodine status in Khogiani district.

The implications of this research extend beyond academic interest. The findings will directly inform policy to strengthen Afghanistan's salt iodization program, drawing lessons from successful models, such as China's (Sun et al., 2017). They will guide interventions for high-risk groups, building on the demonstrated association between low UIC and thyroid dysfunction (Sun and Wang, 2020). Furthermore, the study will provide a model for similar assessments in other underserved regions, contributing to national efforts to achieve Sustainable Development Goals related to nutrition and health (Knowles et al., 2023).

The consequences of inaction are severe. The cognitive impairments from maternal iodine deficiency create lifelong disadvantages, as confirmed by research in India and Norway (Poyesh et al., 2015; Oberlin et al., 2006; McDonald et al., 2023). In Afghanistan's post-conflict setting, addressing iodine deficiency is not only a health priority but also a developmental imperative—an investment in human capital that can break the cycles of poverty. By focusing on Khogiani, this study addresses a critical evidence gap and contributes to the understanding of iodine deficiency in conflict-affected regions.

Ultimately, this research is both an urgent public health intervention and a strategic investment in Afghanistan's future. As the country rebuilds, ensuring optimal iodine nutrition is fundamental to developing the cognitive potential and physical health of the next generation. The findings will provide policymakers, healthcare providers, and international partners with the evidence needed to design effective, context-specific solutions to this persistent yet preventable challenge.

The main objectives of the study are:

- Evaluation of Iodine Deficiency in Children Aged 6–12 Years in Khogiani District.
- Determination of Iodine Levels in Edible Iodized Salt in Khogiani District.

The following main research questions will be answered:

- Are children aged 6–12 years in Khogiani District affected by iodine deficiency?
- Do the iodized salts consumed by households in this district comply with standard requirements?

MATERIALS AND METHODS

Iodine content in the urine is a reliable, accessible, and economical indication of iodine status. Urine is where the majority of the iodine that the body absorbs is eliminated. The majority of analytical techniques for determining urinary iodine concentrations are based on the Sandell-Kolthoff (1937) reduction reaction, a spectrophotometric method used for urinary Iodine concentration. The iodometric titration method is used for the determination of Iodine in salt. Per chloric acid 70%, Vanadium pentoxide, Arsenite Reagent, potassium iodate, starch solution, sodium thiosulfate, and concentrated sulfuric acid are used as materials.

Study Design and Ethical Considerations

A community-based, descriptive cross-sectional study was conducted from February 15 to April 15, 2023, in the Khogiani district of Nangarhar Province, Afghanistan. The study design and methodological approach for assessing iodine deficiency were informed by established protocols by Chudasama et al. (2011), who performed a cross-sectional study on the prevalence of iodine deficiency in 223 school children of both sexes, aged 6 to 12 years from four talukas (subdivisions) of the Kachchh district by estimating urinary iodine using Sandell–Kolthoff reaction along with iodine content in edible salt samples. Additionally, Fahim et al. (2023) found that 38.3% of individuals had micronutrient deficiencies, including anemia, vitamin A deficiency, vitamin D deficiency, and iodine deficiency. According to Meththika et al. (2016), the iodized salt status in Sri Lanka revealed that 98.5% of the population was below the normal range. The resulting data will enable comparison with neighboring regions while highlighting Khogiani's unique needs. The Ethical Review Board of the Nangarhar Public Health Directorate approved this study. Written informed consent was obtained from the parents or guardians of all participating children prior to their enrolment. Participation was voluntary, and families could withdraw from the study at any time without obligation.

Study Area and Participants

The study was conducted in four representative villages (Memla, Perakchil, Wazir, and Lokhi), selected to ensure geographical diversity and socioeconomic variability within the district. These villages were chosen based on population density, accessibility, and preliminary reports suggesting a potential risk of iodine deficiency. School children aged 6–12 years were included in the study. The inclusion criteria were: (1) permanent residency in one of the selected villages for at least six months, and (2) absence of any known thyroid disorders or chronic illnesses. Participants were selected using a random sampling technique from village registries and local school records to ensure a representative sample.

Data Collection and Measurements

Data collection was conducted through a multi-component assessment, which included a structured questionnaire, anthropometric measurements, and the collection of biological and household samples. A structured questionnaire was administered to parents or guardians through direct interviews conducted by trained personnel. The instrument was designed to gather comprehensive data on key areas, including child characteristics such as age, gender, and place of residence; dietary habits, covering primary food and water sources as well as the frequency of seafood and dairy consumption; parental knowledge and practices related to the awareness of iodized salt benefits and salt storage methods; and household socioeconomic status, including monthly family income and parental education and occupation. To ensure the validity and clarity of the questionnaire, it was pretested on a sample of 20 households that were not included in the main study.

Sample Collection

For each participant, a spot urine sample (~10 mL) was collected in a sterile, labelled plastic container during the morning hours. Samples were immediately placed in a cold chain (4°C) and transported to the laboratory within 4 hours of collection. They were stored at −20°C until analysis to prevent iodine degradation (Pieter, 2010). Approximately 50 g of salt was collected from each participant's household in an airtight, light-protected plastic container to prevent iodine loss. Samples were labelled with household identifiers for subsequent analysis.

Laboratory Analysis

Urinary Iodine Concentration (UIC): UIC was determined using the Sandell-Kolthoff reaction, a spectrophotometric method (Skeaff et al., 2012). Briefly, 0.5 mL of urine was digested with 70% perchloric acid to release bound iodine. The iodine then catalyzes the reduction of yellow ceric ammonium sulfate (Ce^{+4}) to colorless cerous (Ce^{+3}) in the presence of arsenious acid. The reaction's progress was measured by optical density (OD) at 405 nm using a UV spectrophotometer (Shimadzu UV mini-1240). A standard curve (0–300 µg/L) was plotted using potassium iodide (KI) standards to quantify iodine concentrations. All samples were tested in duplicate, and results were expressed in micrograms per liter (µg/L).

Salt Iodine Content: Iodine levels in salt were measured using iodometric titration (Vithanage et al., 2016). Five grams of salt were dissolved in 50 mL of distilled water, and 1 mL of 1 M sulfuric acid was added to stabilize iodine. The solution was titrated with 0.005 M sodium thiosulfate ($Na_2S_2O_3$) using a 1% starch solution as an indicator (endpoint: blue to colourless). The iodine content was calculated and expressed as milligrams of iodine per kilogram of salt (mg/kg or ppm).

Quality Control: Laboratory quality control was maintained by including blank samples and standard reference materials in each assay batch. All reagents were of analytical grade.

Statistical Analysis: Data were analyzed using IBM SPSS Statistics version 24.0 (IBM Corp., 2016). Descriptive statistics—including frequencies, percentages, means, and standard deviations—were used to summarize demographic, socioeconomic, and biochemical variables. The normality of data distribution was assessed using the Shapiro-Wilk test. Non-normally distributed variables were log-transformed for analysis. The one-sample t-test was used to compare the mean UIC of the population with the WHO threshold for adequacy (100–199 µg/L). An independent samples t-test was applied to evaluate differences in UIC between genders. Pearson's correlation analysis was employed to examine the relationships between UIC, salt iodine content, and continuous socioeconomic variables (e.g., household income, parental education). A 95% confidence interval (CI) and a p-value of less than 0.05 were considered statistically significant.

FINDINGS

Iodine Deficiency and Salt Quality Assessment

The study revealed significant iodine deficiency among children in Khogiani district, with 13.0% (n=57) exhibiting urinary iodine concentrations (UIC) below the WHO threshold of 100 µg/L, indicating moderate deficiency. Furthermore, household salt testing demonstrated inadequate iodization, with only 15.2% (n=67) of samples meeting the recommended iodine levels of 15–40 ppm, while a staggering 75.1% (n=331) contained no detectable iodine. These findings suggest widespread non-compliance with national salt iodization policies, highlighting a critical public health concern.

Socio-Demographic Characteristics

The study included 438 children (6–12 years) with nearly equal gender distribution: 218 males (50.2%) and 220 females (49.8%). Demographic analysis revealed key insights into the study population (Table 1):

Table 1. *Demographic characteristics of participants (n=438)*

Variable	Frequency	Percentage (%)
Age Group		
6–8 years	211	48.2
9–10 years	113	25.9
11–12 years	114	25.9
Gender		
Male	218	50.2
Female	220	49.8
Edible Salt Type		
Ground (iodized)	98	22.4
Rock salt	8	1.8
Parental Education		
Illiterate (Mother)	405	92.5
Illiterate (Father)	335	76.5
Knowledge of Iodized Salt		
Mothers aware	197	45.0
Fathers aware	333	76.0
Salt Preservation Awareness		
Pay attention	44	10.0
Do not pay attention	394	90.0

As shown in Table 1, the majority of respondents (99%) rely on locally sourced food and water, with 85% dependent on agriculture as their primary income source. Parental awareness regarding iodized salt remained low, particularly among mothers (45% aware compared to 76% among fathers).

Urinary Iodine Concentration (UIC) vs. WHO Standards

UIC analysis classified children based on WHO iodine status thresholds (Table 2):

Table 2. *UIC distribution by gender and WHO classification (n=438)*

UIC Range (µg/L)	Male	Female	Total	Mean UIC (µg/L)	p-value
50–99 (Insufficient)	31	26	57	75.85	**<0.001**
100–199 (Adequate)	185	194	379	150.42	–

Table 2 illustrates that 31 girls and 26 boys have the under-level of UIC. A one-sample t-test confirmed a significant deviation ($p < 0.001$) from WHO standards, with 13.0% (n=57) classified as iodine-deficient.

Household Salt Iodine Content

Salt iodine levels were alarmingly suboptimal (see Table 3):

***Table 3**. Iodine concentration in household salt (n=438)*

Iodine (ppm)	Mean ± SD	Frequency	Percentage (%)
0 (Non-iodized)	0 ± 0	331	75.1
5–14 (Insufficient)	10.86 ± 1.17	40	9.1
15–40 (Adequate)	18.76 ± 2.01	67	15.2

Table 3 demonstrates that 75% (n = 331) of the salt samples labeled as iodized actually contained no iodine and were essentially non-iodized, thereby exacerbating deficiency risks. Furthermore, 9.7% (n=40) contained insufficient iodine, while only 15.2% (n=67) were within the normal iodine range.

UIC by Age and Gender

No significant differences were observed in UIC across age groups (Table 4, p = 0.371):

***Table 4.** Mean UIC by age group*

Age Group	Mean UIC (µg/L)	n	Std. Deviation
6–8 years	138.19	211	37.36
9–10 years	143.23	113	36.00
11–12 years	142.89	114	33.92

Table 4 explains the urinary iodine concentration of each group. Similarly, gender differences were non-significant (Table 5, p = 0.137):

***Table 5.** Mean UIC by gender*

Gender	n (%)	Mean UIC (µg/L)	Std. Deviation
Male	218 (50.2)	138.38	35.75
Female	220 (49.8)	143.11	36.48

Table 5 presents the frequency of male and female participants, comprising 218 males and 220 females, as well as the mean UIC for each gender group. UIC, according to the gender groups, is not significant.p=0.137

Correlational Analyses

Parental Knowledge vs. UIC. A weak but significant correlation (Spearman's ρ = 0.299, p = 0.05) suggested that higher awareness marginally improved iodine status.

Salt Iodine vs. UIC: A positive correlation (Pearson's r = 0.159, p < 0.001) confirmed that households with iodized salt had better UIC levels.

Iodine Deficiency Symptoms. Clinical observations (Table 6) indicated that 86.4% (n=381) were asymptomatic, while 6.1% (n=20) reported weakness, 1.8% (n=5) had palpable thyroid nodules, and 1.2% (n=8) exhibited dry skin/thinning hair.

Table 6. *Clinical symptoms observed (n=438)*

Symptom	Frequency	Percentage (%)
No symptoms	381	86.4
Weakness	20	6.1
Palpable thyroid nodules	5	1.8
Dry skin/thinning hair	8	1.2

Table 6 demonstrates that Goitre was absent, but thyroid nodules, weakness, nodules, dry skin/and thinning hair were concentrated. The 13% prevalence of iodine insufficiency (UIC <100 µg/L) in our study exceeds the 11.6% reported by Kapil et al. (2004) in their multi-center Indian study. This discrepancy likely reflects important geographical and socioeconomic factors specific to the Khogiani district.

DISCUSSION

Iodine serves as an indispensable micronutrient for thyroid hormone synthesis, which regulates the metabolic activity of virtually all critical organs, including the liver, brain, and central nervous system (Abbag et al., 2021). The thyroid hormones thyroxine (T4) and triiodothyronine (T3), which contain iodine as an essential structural component, play a pivotal role in neurodevelopment, particularly during fetal growth and early childhood (Aydın, 1993).

In Afghanistan, the severity of iodine deficiency has been well-documented, with the National Public Nutrition Policy (2015-2020) reporting a 29.5% prevalence among children aged 7-12 years (Oberlin et al., 2006). This high prevalence is particularly concerning given the irreversible cognitive impairments associated with iodine deficiency during critical developmental periods (Eriksson et al., 2023). The situation in neighboring regions further emphasizes the gravity of the problem. Endemic iodine deficiency has been consistently reported in Paktia, Kapisa, and Parwan provinces, with particularly alarming findings from the Panjshir Valley, where a 2002 nutrition survey revealed that 50.9% of mothers exhibited visible goiter (Fahim et al., 2023). These findings collectively underscore the persistent and severe nature of iodine deficiency disorders (IDD) across Afghanistan.

Our study's assessment of Urinary Iodine Concentration (UIC) provides crucial insights into the population's iodine status. The finding that 13% of children exhibited UIC levels below 100 µg/L is consistent with global evidence demonstrating the association between low UIC and adverse thyroid outcomes (Verhagen et al., 2020). Specifically, our observation that 1.8% of children had palpable thyroid nodules aligns with the well-established relationship between chronic iodine deficiency and nodular thyroid disease (Zimmermann et al., 2015). This prevalence is notably higher than the 1% reported by Sharma et al. (2021) in Gujarat, India, but significantly lower than the 23.9% deficiency observed by Gururaj et al. (2020) in Raichur district, Karnataka. These disparities may reflect several factors: regional variations in dietary iodine intake (Jauharia et al., 2020), differences in salt iodization programs (Tadesse et al., 2022), and variations in dietary goitrogens (Zimmermann et al., 2015).

The 13% prevalence of iodine insufficiency in our study exceeds the 11.6% reported by Kapil et al. (2020). Our findings revealed notable intra-district variations, with micro-geographical differences attributed to variations in access to iodized salt, differences in traditional dietary practices, uneven implementation of public health interventions, and variability in groundwater iodine content (Watts et al., 2015). The overall mean UIC of 140.8 µg/L, while within the adequate range, masks important subpopulation vulnerabilities, emphasizing the need for geographically targeted interventions (Janny et al., 2020).

Perhaps our most alarming finding was that 84.8% of salt samples had inadequate iodine content (<15 ppm), despite being marketed as iodized. This implementation failure mirrors observations in other resource-limited settings (Shaikh et al., 2022) and suggests systemic weaknesses. Several factors likely contribute, including inadequate quality control, poor storage conditions that lead to iodine loss (Mirete et al., 2023), economic incentives for producers, and limited regulatory capacity. The significant positive correlation between salt iodine content and UIC ($r = 0.159$, $p < 0.001$) provides empirical support for the role of salt iodization.

When contextualized within the broader literature, the 13% prevalence of UIC <100 µg/L is lower than Afghanistan's national average but higher than the level considered optimal. This positioning suggests that while the district may fare better than some Afghan regions, it still falls short of international standards. The poor quality of salt iodization indicates that current prevention strategies are insufficient (Knowles et al., 2023).

Our findings have several important implications for public health practice, including the need for strengthened salt iodization programs, possibly through public-private partnerships (Diosady et al., 1999); community education, given the low parental awareness (Zimmermann et al., 2015); targeted supplementation for high-risk groups; and enhanced monitoring. While providing important insights, our study has limitations: the cross-sectional design limits causal inferences; we did not assess thyroid function tests; dietary recall data were limited. Future longitudinal studies incorporating these elements would enhance understanding of IDD in this context.

CONCLUSION

Our study reveals persistent iodine deficiency in the Khogiani district, primarily driven by inadequate salt iodization despite existing policies. While the prevalence is lower than some regional reports, the 13% deficiency rate and widespread poor salt quality demand urgent public health attention. The geographical clustering of clinical symptoms suggests the need for targeted interventions in high-burden villages. Our findings underscore that achieving universal iodine adequacy will require multi-sectoral efforts combining regulatory strengthening, producer accountability, and community education.

AUTHORS CONTRIBUTIONS

- Bashir Ahmad Bashir designed the study, collected the data, analyzed the results, and wrote the article.
- Ziaudin Azimi designed the study and supervised the research
- Mirwais Zazai conducted the experimental works in the laboratory
- Jawed Ahmad Oneeb also conducted experimental works in the laboratory
- All authors critically reviewed and approved the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The Authors declare no conflict of interest.

ETHICAL APPROVAL

Verbal consent was obtained from each patient's guardian. The aggregate data were used, excluding patient-identifying data. Therefore, we did not receive the patient's written informed consent.

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