PACIFIC JOURNAL OF MEDICAL SCIENCES
{Formerly: Medical Sciences Bulletin}
ISSN: 2072 – 1625

Pac. J. Med. Sci. (PJMS)
www.pacjmedsci.com. Email: pacjmedsci@gmail.com.

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ABSTRACT:

The effectiveness of the universal salt iodization strategy in the control and elimination of iodine deficiency in a community requires systematic monitoring of urinary iodine concentration, which is the key biochemical indicator recommended for assessing the impact of iodine deficiency control programs. Published data on the salt iodization programme for control of iodine deficiency in the Solomon Islands is scanty. The aims of this study were to determine the iodine content of salt in the households and the urinary iodine concentrations (UIC) in schoolchildren, age 6 – 12 years, in Honiara, Solomon Islands. This was a prospective school-based study. Multistage cluster sampling method was used for selecting the study population. Simple random sampling technique was used to select 19 of the 28 primary schools in Honiara Solomon Islands. The iodine content in salt samples was measured using the single wavelength semi-automated WYD Iodine Checker Photometer. UIC was estimated using the Sandell-Kolthoff reaction. Salt was available and used in 99.5% of the households. The mean iodine content in household salt samples was 55.2 ± 17.7ppm. The iodine content was ≥ 15.0ppm in salt samples from 99.1% of households. Data indicates successful implementation of universal salt iodisation strategy. Median UIC for all the children was 328.0ug/L, Inter-quartile range was 210.38 – 437.0ug/L. UIC in 97.2% of all the children was ≥ 100ug/L and 0.7% had UIC below 50ug/L. Median UIC values for the male and female children were 337.0ug/L and 325.0ug/L respectively. UIC in 97.1% of male and 97.4% of female children was ≥ 100ug/L. Data indicate that iodine deficiency is not a public health problem among schoolchildren, age 6 – 12yrs, in Honiara. Our findings indicate the need for an efficient, sustainable, and functional monitoring system to strengthen and improve on the achievements of the USI strategy in Honiara, Solomon Islands

Key Words: Solomon Islands, Honiara, Iodized salt, Urinary Iodine, Iodine deficiency.

Received: June 2010; Accepted: July 2010

INTRODUCTION:

The trace element Iodine is required for the biosynthesis of the thyroid hormones (Thyroxin and Triiodothyronine), which are essential for normal growth and development [1, 2]. Low dietary intake of iodine or consumption of foodstuffs containing goitrogens can significantly impair the bioavailability of iodine leading to a spectrum of conditions known as iodine deficiency disorders (IDD) [1, 2].

According to the WHO/UNICEF/ICCIDD expert committee, the harmful effects of IDD are manifold, depending on the extent of iodine deficiency [1, 2, 3]. The prevalent forms of IDD in most developing countries are the more subtle degrees of mental impairment that occur in apparently normal children with low dietary intake of iodine [1, 4]. Its manifestations include poor performance of the children in school and in psychometric tests, reduced intellectual ability and impaired motor functions [1, 4]. The World Health Assembly in 1990 recognized that iodine deficiency (ID) is a significant public health problem in most developing countries, and that it is the world’s greatest single cause of preventable mental impairment [1, 3].

Universal salt iodization (USI), a policy of iodizing all salt for human consumption, is the agreed strategy for the control and elimination of IDD in affected populations [1 – 5]. Successfully and sustainable implementation of the USI strategy requires continuous monitoring of the process, impact and sustainable indicators in the affected communities [1, 3, 6, 7]. The recommended process indicator for monitoring and evaluating USI is the assessment of iodine content in salt in the households [1, 6]. The recommended principal impact indicator of USI is the assessment of Urinary Iodine concentration (UIC) among school-age children in the target population [1, 3, 7].

The sustainable indicator is used to assess whether iodine deficiency has been successfully eliminated and to judge whether achievements can be sustained and maintained for several years. The sustainable indicator involves a combination of median UIC in the target population, availability of adequately iodized salt at the household level and a set of programmatic indicators that are regarded as evidence of sustainability [1, 3, 6, 7].

An important issue at present in some developing countries is the long-term sustainability of salt iodization programs, which require constant monitoring of the iodine status of the population [1, 3, 8]. Failure to monitor can cause a breakdown of IDD control programs. In addition, poorly monitored programs can result in excessive intake of dietary iodine which is associated with risks of adverse health consequences, such as, Iodine-Induced Hyperthyroidism (IIH) [1, 6 – 8].

A thorough search of the literature indicates that no published data is available on the status of iodine nutrition in the Solomon Islands [9]. There is scanty information on the salt iodization program for control of IDD in the Solomon Islands [9]. In addition, there are no data to indicate systematic monitoring of the iodine content of salt in the Solomon Islands [9]. Furthermore, no data is available on the median UIC in school-age children [9]. This study was prompted by the apparent lack of published data on the status of iodine nutrition in the Solomon Islands.

The aims of the current study were to determine the iodine content of salt in the households and the UIC in schoolchildren, age 6 – 12 years, in Honiara, Solomon Islands.

MATERIALS AND METHODS:

The Solomon Islands is an Archipelago within the Southwest Pacific, located approximately 1,900 km Northeast of Australia, and about 485 km East of Papua New Guinea [10 – 12]. The Solomon Islands is made up of six large and numerus small islands with a total population of about 500.000 people [10 – 12]. The highest point is about 2.447m above sea level [10 – 12].

This study was carried out in Honiara, the national capital city and the biggest town in Solomon Islands. It is located on the Island of Guadalcanal, which is the biggest of the six big islands. Honiara is situated at latitude 9^0 28’ South and Longitude 159^0 49’ East, along the coastline of north Guadalcanal [13]. Honiara functions as a separate entity, with the Honiara city council responsible for many aspects of the health of the urban population of about 60,000 people [12].

This was a prospective school-based study. The study population consisted of School children in the age group 6 – 12 years. According to the primary school enrolment list prepared by the Ministry of Education and Human Resource Development (MEHRD) [14], there were 28 registered primary schools located in different areas in Honiara at the time of this study. The primary schools with a total population of 7737 children in the age range 6 – 12 years were officially in the Preparatory to Standard Six category [14].

Multistage cluster sampling method was used for selecting the study population. Simple random sampling technique was used to select 19 of the 28 primary schools that participated in this study.

Calculation of the sample size was based on a design effect of three, a relative precision of 10% and confidence level (CL) of 95%. As there was no available information on likely prevalence rate of IDD in Honiara, an assumed prevalence rate of 25% was used. With a predicted non-response rate of 10%, the sample size of 500 school-age children was obtained [1]. This number was ten times higher than the 50 recommended by the WHO/UNICEF/ICCIDD expert committee for school-based studies on the prevalence of IDD in an affected population [1]. The justification for selecting a larger sample size was the lack of data on the prevalence rate of IDD in Honiara [3].

The total enrolments for each of the 19 randomly selected primary schools were listed. In addition, the enrolments and ages for children in each of the grades in the selected primary schools were also listed. All children below 6yrs of age and above 12yrs of age were identified and excluded from the study. The sample size for each school was calculated using the “proportionate to population size (PPS)” cluster sampling techniques [3]. For each school, each of the children in the age group 6 – 12yrs was assigned a computer-generated random number. The required number of children from each school was then selected by simple random sampling using the randomly generated number list.

Two cohorts of children were selected from each primary school using two separate randomly generated number lists. Those in the first cohort were involved in the sampling for household salts and the filling of the questionnaire, while those in the second cohort provided urine samples for analysis of urinary iodine. Fieldwork for this project was conducted between January and May 2007.

A total of 464 schoolchildren from the selected primary schools participated in the collection of salt samples and filling of questionnaires. The parent or guardian of each child was requested to complete the questionnaire and to put about three teaspoons (10 to 15g) of the salt available in the household into a zip-lock polythene bag provided for that purpose.

For the collection of urine samples a total of 500 schoolchildren from the selected primary schools participated. On the spot urine sample was collected from each of the consented children. Each urine sample was transferred into properly labelled plastic tube with tight fitting stopper that was further sealed with special plastic bands.

The urine and salt samples were packed into separate containers and transported by airfreight to Port Moresby Papua New Guinea (PNG) after detailed consultation with the Solomon Islands Quarantine Office in Honiara. On arrival in Port Moresby the packages were transported to the Micronutrient Laboratory (MNL) in the School of Medicine and Health Sciences (SMHS) University of Papua New Guinea (UPNG) and appropriately stored till required for analyses.

The iodine content in salt samples was measured using the WYD Iodine Checker [15]. Internal bench quality control (QC) for daily routine monitoring of performance characteristics of the WYD Iodine Checker was by the Westgard Rules using Levy-Jennings Charts prepared for iodized salt samples obtained from the National China Reference Laboratory. The percent coefficient of variation (CV) ranges from 2.5% to 5.0% throughout the analysis.

The spectrophotometric method of Sandell-Kolthoff reaction was used for the assay of urinary iodine after digesting the urine with Ammonium Persulfate in a water–bath at 100°C [1]. Internal bench QC characterization of the assay method was by the Levy-Jennings Charts and the Westgard Rules. External QC monitoring of the urinary iodine assay procedure was by Ensuring the Quality of Urinary Iodine Procedures (EQUIP), which is the External Quality Assurance Program (QAP) of the Centers for Disease Control and Prevention (CDC), Atlanta, Georgia, USA and also by the QAP of the Institute of Clinical Pathology and Medical Research (ICPMR), Westmead Hospital, Sydney, NSW, Australia.

Microsoft Excel Data Pack 2003 and SPSS-PC software (version 11) were used for the statistical analyses of the data. Kolmogorov-Smirnov and Shapiro-Wilks tests were used to assess normality of the data. Mann Whitney U test was used for differences between two groups; Kruskal-Wallis and Friedman were used for comparison of all groups.
Analysis of variance (ANOVA) was also used to compare differences between groups. Scheffe test was used for post-hoc analysis. $P < 0.05$ was considered as statistically significant.

The data were interpreted using the WHO/UNICEF/ICCIDD and other criteria [1, 7, 8, 15, 16]. Iodine deficiency was not a public health problem in the target population, if at least 90.0% of households were using salt with iodine content of 15.0ppm or more, the median urinary iodine concentration (UIC) was not below 100.0ug/L and the 20th percentile UIC was not below 50.0ug/L [1, 7, 8, 16]. Specific cut-off points for UIC were used for classifying status of iodine nutrition into different degrees of public health significance [1, 7, 8, 16].

Ethical clearance and permission for this study was obtained from the Ethical and Research Grant committee in the SMHS UPNG. Permission was also obtained from the Solomon Islands Medical Research and Ethical Committee and from appropriate authorities in Solomon Islands: the Ministry of Education and Human Resource Development, Honiara City Council (Education Section), and the Headmasters and Headmistresses of appropriate Primary Schools. Parental consent and approval were obtained from parents and / or Guardians of the children selected for the study. The verbal approval of each child with parental consent was also obtained at the time of urine collection. International ethical guidelines for epidemiological studies were implemented in this study [17].

RESULTS:

Each of the 464 children that consented to bring salt samples and complete the questionnaire was from a different household. A total of 432 salt samples (between 30 – 35g) in iodine-free polyethylene bags were received. This gave a response rate of 93.1%.

The frequency distribution of the iodine content (ppm) in the salt samples from the households indicates a wide scatter with a range of 10.0 to 99.0ppm. The mean iodine content in the salt samples was 55.17 ± 17.69ppm (Mean ± Standard Deviation). The median was 54.58ppm and the 95% confidence interval (95% CI) was 52.91 – 56.25ppm. The iodine content was equal to or greater than 15ppm in salt samples from 428 (99.07%) households.

The distribution of households according to the range of iodine content in salt samples is presented in Table 1.

A total of 431 (92.9%) of the 464 questionnaires distributed were returned and were suitable for analysis. The results indicated that salt was regularly used in 429 (99.5%) households. Respondents in 257 (59.6%) households indicated using iodised salt at home; 67 (15.5%) respondents indicated that they were not using iodises salt and 107 (24.8%) were not sure of using iodised salt at home.

In 225 (52.2%) households the respondents did not know the importance of iodised salt. Friends, relatives and neighbours were the major sources of information about the use of iodised salt as indicated by 227 (62.4%) of the respondents that indicated using iodised salt or nor sure of using iodised salt.

Of the 429 households that regularly use salt 390 (90.9%) of them usually purchase salt from supermarkets and trade stores, 33 (7.7%) purchase salt from local markets. When asked about the brand of salt commonly used at home, 164 (38.2%) of the respondents did not know the brand of salt commonly used in the households; however the most popular brand was Saxa salt used in 96 (22.4%) households, followed by Jumbo salt used in 61 (14.2%) households, Sky salt used in 54 (12.6%) households and others used in 54 (12.6%) households.

Fine table salt was used in 369 (86%) households, coarse salt was used in 27 (6.3%) households and 33 (7.7%) were not sure. Salt was kept in plastic containers in 298 (69.5%) households compared to 107 (24.9%) households using glass containers; both were used in 24 (5.6%) households. Salt was always kept in closed containers in 389 (90.7%) households. Sea-food were consumed frequently in 152 (35.4%) households, compared to 226 (52.7%) households that consume sea-foods once in a while and 51 (11.9%) households that did not remember eating seafood.

Of the 500 schoolchildren recruited for this section of the study only 462 (92.4%) gave consent. Assay for UIC was carried out in all the 462 urine samples.

The median UIC was 328.0ug/L, with a mean of 353.7 ± 189.57 ug/L. The Inter-quartile range was 210.38 – 437.0ug/L and the 95% CI of the UIC was 310.67 – 345.33ug/L.

A total of 97.18% (449) of all the children had UI concentration $\geq$ 100ug/L and only 0.65% (3) had UI concentration < 50ug/L. The 20th percentile UIC was 187.5ug/L.

Distribution of the children according to the range of UIC and status of iodine nutrition is presented in Table 2. None of the children had UI concentration below 20ug/L, and only 13 (2.81%) of them had UIC below 100ug/L.

A total of 257 (55.63%) of the children had UIC over 300ug/L, which indicates risk of developing adverse health consequences. Further analysis of the data indicates that 170 (36.8%) children had UIC in the 300 to 500ug/L range and 87 (18.83%) had UIC greater than 500ug/L.

For further interpretation, the UIC data was separated and analysed according to gender. There were 236 (51.1%) males and 226 (48.9%) females. Table 3 shows the UIC results for the male and female schoolchildren.

The median UIC for the male and female schoolchildren were 337.0ug/L and 325.0ug/L respectively.

There was no statistically significant difference between the mean UIC of the male and female schoolchildren. A total of 229 (97.06%) male and 220 (97.35%) female schoolchildren had UIC greater than 100ug/L. The 20th percentile UIC for the male and female schoolchildren was 194.5ug/L and 186.0ug/L respectively.

Table 4 shows the distribution of the male and female schoolchildren according to the range of UIC and status of iodine nutrition. The UIC values in 134 (56.78%) male and 123 (54.42%) female schoolchildren were over 300ug/L. When these data were analysed further, 91 (38.56%) of the male and 77 (34.1%) of the female children had UIC in the 300 – 500ug/L range.

In addition, 43 (18.2%) of the male and 46 (20.4%) of the female children had UIC greater than 500ug/L. No statistically significant differences were obtained in the number of male and female Schoolchildren in the various ranges of UIC.

The median UIC for all the schoolchildren and for the male and female children are in the range equal to or greater than 300ug/L, which indicates greater risk of developing Iodine-induced Hyperthyroidism (IIH).

Table 1: Iodine content of salt samples from the 432 households

Iodine content in salt samples	Households No. of salt samples (%)
< 15ppm	4 (0.93%)
≥15ppm	428 (99.07%)
15 – 30ppm	31 (7.18%)
> 30ppm	397 (91.9%)

Table 2: Number (%) of school-age children in the different ranges of urinary iodine concentrations (UIC) and status of iodine nutrition (n = 462)

Range of UIC (ug/L) [1]	Status of iodine nutrition [1]	No. of school-age children (%)
< 20	Severe	0
20 – 49	Moderate	3 (0.65)
50 – 99	Mild	10 (2.16)
100 – 199	Optimal	90 (19.48)
200 – 299	Risk of IIH*	102 (22.08)
≥ 300	Greater risk of IIH	257 (55.63)

*IIH: Iodine-Induced Hyperthyroidism

Table 3: Urinary iodine concentrations (UIC) in the male and female school-age children

	Males (n = 236)	Females (n = 226)
Median UIC (ug/L)	337.0	325.0
Interquartile Range UIC (ug/L)	217.5 – 432.1	205.8 – 443.8
Mean UIC (ug/L)	354.2	353.2
Std Dev	185.0	194.7
95% CI: UIC (ug/L)	330.5 – 377.9	327.7 – 378.7
20th Percentile UIC (ug/L)	194.5	186.0
Percent (n) with UIC ≥ 100ug/L	97.03 (229)	97.35 (220)
Percent (n) with UIC < 50ug/L	0.42 (1)	0.88 (2)

Table 4: Number (%) of male and female school-age children in the different ranges of urinary iodine concentrations (UIC) and status of iodine nutrition

Range of UIC (ug/L)	Status of iodine nutrition	Male (n = 236) No. (%)	Female (n = 226) No. (%)
< 20	Severe	0	0
20 – 49	Moderate	1 (0.42)	2 (0.88)
50 – 99	Mild	6 (2.54)	4 (1.77)
100 – 199	Optimal	43 (18.22)	47 (20.8)
200 – 299	Risk of IIH	52 (22.03)	50 (22.12)
≥ 300	Greater risk of IIH	134 (56.78)	123 (54.42)

DISCUSSION:

WHO/UNICEF/ICCIDD expert committee recommended the use of one of three variables for the assessment and monitoring of iodine nutrition in a population [1]. The three recommended variables are, the proportion households using adequately iodised salt, the UIC in an adequate sample size of schoolchildren (age 6 – 12 years) and the prevalence of goitre in the population [1, 3]. In the present study two of the recommended variables were used to assess the status of iodine nutrition in Honiara, Solomon Island.

The iodine content of salt is the indicator of the salt iodization process. The principal indicator of the impact of salt iodization is the UIC among schoolchildren, age 6 – 12years [1, 2, 3].

School children in the 6 – 12 years age group are recommended for the assessment of iodine nutrition in a population because of their high vulnerability to iodine deficiency and easy accessibility in the community [1]. The school-based approach was used in this study because of the high enrolment and attendance of both male and female children in primary schools in Honiara, Solomon Islands [1, 14].

The non-response rate of 6.9% obtained in this section of the study was lower than the predicted 10.0% non-response rate used in calculating the sample size. The most common reason given by the 32 (6.9%)

children that did not provide salt samples was because the salt in the house had just ran out or was not enough.

Testing of iodine content in household salt is the most important "process" indicator for monitoring progress in the implementation of USI, which is the most effective and sustainable long-term public health measure for the prevention and control of iodine deficiency [1, 6].

The mean (55.17ppm) iodine content in the salt samples from the households was higher than the values reported for household salt samples in various cities in PNG [18 – 21].

According to the WHO/UNICEF/ICCIDD criteria [1, 8, 16] at least 90.0% of households in the community should be using salt with iodine content of not less than 15.0ppm. Thus, adequately iodised salt was used in 99.07% of the households in Honiara (Table 1). This coverage of the use of adequately iodised salt indicates compliance with the current WHO/UNICEF/ICCIDD criteria that indicates implementation of the USI strategy [1, 8, 16]. Similar coverage has been reported for households in some cities in PNG [18 – 21].

In the present study, because of logistical reasons it was not possible to accurately assess the discretionary per capita consumption of salt in the households. The mean iodine content of the salt samples in the households was 55.17ppm. Assuming that the discretionary per capita intake of salt in the households was about 5 – 10g per day, the mean discretionary per capita intake of iodine should be between 275.85 to 551.7ug per day. Factoring in the about 20% loss of iodine in salt during storage and preparation of food, the calculated discretionary per capita intake of iodine should be between 220.68 – 441.36ug per day. This indicates that the mean and median iodine content in salt samples used in the households are adequate for the prevention and control of iodine deficiency [1, 3, 8, 16].

The data, according to the WHO/UNICEF/ICCIDD criteria [1, 3, 8], indicates success in the implementation of the USI strategy in Honiara at the time of this study. The situation analysis of the status of the USI strategy in Honiara can be characterized as "existent but needing strengthening" [1, 8]. WHO/UNICEF recently proposed specific criteria for the categorization of salt iodisation programs in various areas within countries [8]. According to these criteria [8], salt iodization in Honiara should be in Group one, because over 90% of households have access to adequately iodised salt. Therefore, according to

WHO/UNICEF guidelines [8], authorities in Honiara should strive to sustain the achievement of USI and periodically reassess the salt iodization programme and the iodine status of the population.

Despite the success in the implementation of USI there is need to enhance the advocacy and awareness on the importance and appropriate use of iodised salt which is already available and accessible to communities in Honiara. This is of significance because analysis of the questionnaires indicated that 52% of the respondents do not know the use of iodised salt and 15.5% indicates that they do not use iodised salt at home. Since 99.07% of households are using adequately iodised salt, there is the likelihood that people in these households, especially the elderly, may be consuming relatively large amount of iodized salt per day, putting them at risk of developing adverse health consequences in the long term.

Effective implementation of the USI strategy requires systematic monitoring of UIC, which is the key biochemical indicator recommended for assessing the impact of IDD control programs [1].

The 38 schoolchildren that did not provide the on-the spot urine samples represent a non-response rate of 7.6%, which is less than the 10% assumed non-response rate used in the calculation of sample size.

The median UIC obtained for all the schoolchildren was 328.0ug/L and the 20th percentile UIC was 187.5ug/L. In addition, 97.18% of all the children had UIC greater than or equals to 100ug/L.

Thus, according to the current WHO/ICCIDD/WHO criteria [1, 7, 8], iodine deficiency was not of public health significant among school children, age 6 – 12yrs, in Honiara, at the time of this study. This was strongly supported by the data in Table 2 indicating that mild to moderate status of iodine nutrition was present in only 2.8% of the school-age children.

The median and 20th percentile UIC for the male (337.0ug/L and 194.5ug/L) and female (325.0ug/L and 186.0ug/L) schoolchildren indicate optimal status of iodine nutrition.

The results also show that mild to moderate status of iodine nutrition was prevalent in 2.97% (7) of male and 2.65% (6) of female schoolchildren (Table 4), which indicates that iodine deficiency was not of public health significance.

The median UIC obtained for all the schoolchildren (328.0ug/L) and for the male (337.0ug/L) and female (325.0ug/L) schoolchildren indicate that the status of iodine nutrition can be classified as excessive iodine intake (range over 300ug/L).

These median UIC values were higher than those reported for school children, age 6 – 12yrs in Southern Highlands Province Papua New Guinea (48.0ug/L) [19], Honduras (287ug/L), Nicaragua (259ug/L) and El Salvador (251ug/L), but lower that those reported for schoolchildren in Chile (565ug/L), Ecuador (590ug/L), Brazil (1013ug/L) and Mexico (1150ug/L) [22].

Excessive intake of iodine, indicated by median UI concentration over 300ug/L, has been reported in many countries, particularly when salt iodization is excessive and poorly monitored [1, 7, 18, 21, 22]. Although most individuals can tolerate high intake of iodine per day without apparent problems, daily intake in excess of 1000ug per day can be potentially harmful to susceptible individuals [1, 7, 21, 23].

Ideally, intake of over 300ug/L iodine per day should be discouraged, particularly in communities with previous history of iodine deficiency [1, 7, 21, 23]. This is because, in such communities, individuals, particularly the elderly with autonomous nodules that were previously iodine deficient may develop iodine-induced hyperthyroidism (IIH) few years after exposure to either normal or high intake of iodized salt [1, 23].

However, in the community the problems that can be caused by excessive intake of iodine are minor compared to those that can be caused by inadequate intake leading to iodine deficiency.

Thus, the concept that "it is better to consume more iodine per day than to consume less, particularly for the vulnerable groups (women, children and infants) in the community [1, 4, 7, 8],. The best concept recommended by WHO/UNICEF/ICCIDD [1, 8] is to ensure the availability and appropriate use of adequately iodized salt in the community. This further emphasizes the notion that sustainable optimal iodine nutrition and consolidation of the current achievement of elimination of iodine deficiency, as a public health problem, among schoolchildren requires continuing effective monitoring and regular evaluation of the implementation of the USI strategy in Honiara, Solomon Islands.

CONCLUSION:

The present study indicates that over 99.0% of households in Honiara are using adequately iodized salt. Although this study did not evaluate other sources of iodine, the data strongly supports the use of salt as the major vehicle for iodine supplementation in Honiara Solomon Islands.

Iodine deficiency was not of public health significance among the schoolchildren age 6 – 12 years in Honiara. However, it is important for program planners to carry out intensive nutrition education, information, and awareness campaigns to advocate for appropriate use of iodised salt.

This process must be accompanied by effective monitoring to guard against continuous excessive consumption of iodine as indicated by the 56.78% of male and 54.42% of female school-age children in the over 300ug/L range of the UIC.

Our findings indicate the need for an efficient, sustainable, and functional monitoring system to strengthen and improve on the achievements of the USI strategy in Honiara, Solomon Islands.

ACKNOWLEDGEMENTS:

We thank Professor John Vince for his interest and support. We acknowledge the four volunteers Brian Soma, Linray, Esmy and Anisi for their assistance during the field work; the Head teachers, primary school teachers and all the school-age children for their cooperation and participation in this project; Philip Modudula, Sampson Grant, and all the technical staff in Biochemistry for their support and assistance.

We also thank Dr. K. Caldwell and Dr. A. Makhmudov in the CDC/CCEHIP/NCEH USA for providing the urine standards used to set up the quality control in the micronutrient laboratory.

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