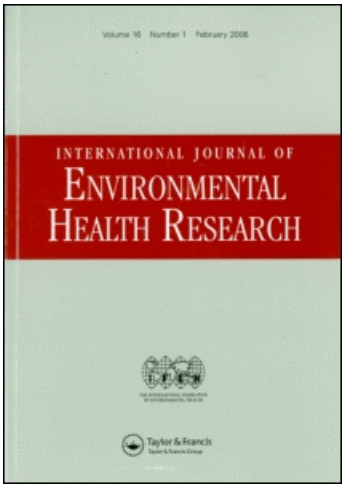

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Determination of urinary iodine in school children of the Hhohho region in Swaziland

SALIA M. LWENJE, JONATHAN O. OKONKWO, VICTOR S. B. MTETWA, AUDREY G. GAMEDZE, JABU A. MAVUNDLA and MBUSO M. SIHLONGONYANE

University of Swaziland, Chemistry Department, Kwaluseni, Swaziland

Urinary iodine was measured in urine samples collected from 399 school children in the Hhohho region of Swaziland. Thirteen, 27, and 48% of the samples were found to contain ≤ 20, ≤ 50 and $\leq 100\ \mu g I\ dm^{-3}$ respectively. These values indicate that there is substantial iodine deficiency in the Hhohho region. A correlation was found between the severity of iodine deficiency and the physiographic region where the sample was obtained; the highveld with a mean urinary iodine concentration of $97\ \mu g\ dm^{-3}$ being most at risk of iodine deficiency whilst the lowveld with $134\ \mu g\ dm^{-3}$ was least at risk.

Keywords: urinary iodine; school children; Swaziland.

Introduction

Iodine is an essential element required by the thyroid gland for the synthesis of thyroid hormones. The thyroid hormones play a crucial role in the regulation of the growth, development and metabolism of nearly all tissues of the body. The normal adult intake of iodine should be at least $100\ \mu g\ day^{-1}$, more in pregnant and lactating women. Below this level, insufficient amounts of thyroid hormones may be produced resulting in recognized manifestation of iodine deficiency for which the term 'iodine deficiency disorders' (IDDs) has been coined. The IDDs include abortions, stillbirths, low birth weight, deaf-mutism, short stature, mental retardation and goitre and its complications.

Iodine, being a mineral, cannot be synthesized. Hence, in the absence of dietary fortification, the primary source of iodine is the soil. The iodine in the soil is, however, leached by rain and snow and carried to the oceans by rivers. Hence mountainous areas and areas with heavy precipitation are generally found to have iodine deficient soils (Hetzel 1989, Dissanayake and Chandrajith 1996). Plants grown in iodine deficient soils are deficient in iodine and hence animals and humans dependent on these plants for food are also iodine deficient and at risk of IDDs.

Iodine deficiency blankets large parts of the world with about one billion people at risk (Dunn *et al.* 1993). Massive national and international efforts to assess and control iodine deficiency are underway, spurred on by pledges of UNICEF, WHO, the United Nations World Summit for children, and others, to eliminate it by the year 2000. The International Council for the Control

Correspondence to: Dr Salia M. Lwenje, Department of Chemistry, University of Swaziland, P/Bag 4, Kwaluseni, Kingdom of Swaziland.

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of Iodine Deficiency Disorders (ICCIDD) came into existence in 1986 to aid this cause. In Swaziland the Ministry of Health, in conjunction with the National Nutrition Council and other local organizations such as the local UNICEF and WHO offices, is coordinating efforts to achieve this goal. The salt iodization regulations gazetted in March 1997 require all salt sold in the country for human and animal consumption to be iodized (Swaziland Government 1997).

A preliminary study carried out by Todd (1993) on behalf of the National Nutrition Council showed that there was severe IDD in the Hhohho and Manzini regions while the Shiselweni region showed moderate IDD and the Lubombo region showed mild to moderate IDD. However, this study was very limited, only four schools (one in each of the four administrative regions) were investigated. In this paper results of a much wider investigation of iodine deficiency in school children of the Hhohho region are given. Similar investigations in the other three regions are still ongoing.

Ingested iodine is rapidly absorbed through the gut and is subsequently excreted by the kidney. The level of excretion correlates well with the level of intake so that it can be used to assess the level of iodine intake (Hetzel 1989). Urinary excretion levels of less than 100 μg dm^{-3} urine indicate mild iodine deficiency, while values less than 50 and 20 μgI dm^{-3} urine indicate moderate and severe deficiency, respectively (Dunn *et al.* 1993).

Most available methods for urinary iodine determination include an initial step in which the urine is either digested in a strong acid or ashed at a high temperature. The iodide is then measured by its catalytic action on the reduction of cerium (IV) by arsenic (III) in the Sandell – Kolthoff reaction (Sandell and Kolthoff 1937)

$$2Ce^{4+} + 2I^- \rightarrow 2Ce^{3+} + I_2$$

$$I_2 + As^{3+} \rightarrow As^{5+} + 2I^-$$

The course of the reaction can be followed by the disappearance of the yellow colour of cerium (IV) as it is reduced. With all other reactants held constant, the rate of reaction is directly proportional to the amount of iodide catalysing it. The reaction can detect iodine levels down to several nanograms (Dunn *et al.* 1993). Sulphuric acid and chloride are both important components of the reaction mixture: sulphuric acid increases the reaction rate while chloride stabilizes it by inhibiting the oxidation of iodide to iodate. The digestion or ashing pretreatment is necessary to remove substances such as nitrite, thiocyanate or iron (II) that might interfere by reducing cerium (IV) or oxidizing arsenic (III).

Methods

Sampling site

Swaziland occupies about 17 000 square kilometres between the 25th and 28th parallels of latitude in South East Africa. The country's altitude ranges from about 1.8 km at a summit in the North West to about 25 m above sea level on the banks of the Usuthu river in the Eastern part of the country. The Hhohho region is about 3600 square kilometres in the Northwestern part of the country (Murdoch 1970).

Sampling

Urine samples were collected from 10 primary schools around the Hhohho region of Swaziland during June 1997. The 10 schools were selected randomly. A minimum of 40 children from

grades 1 to 4 were selected randomly and urine from these was collected directly into polyethylene wide mouthed bottles with liquid tight lids. The age and sex of each child was recorded. The samples were immediately transported to the laboratory were they were stored in a deep freezer until just before analysis.

Analysis

The urine samples were analysed using the method of Wawschinek as modified by Dunn *et al.* (1993).

Reagents and solutions

Chloric acid. Potassium chlorate (500 g; (UnivAR) was dissolved in 910 cm^3 of deionized water and heated for several hours until most of it had dissolved; 375 cm^3 of 70% perchloric acid (UnivAR) was slowly added with constant stirring. The resulting solution was stored in the freezer overnight and filtered the next day on a Buchner funnel with Whatman #1 filter paper. The solution was stored in a refrigerator.

Arsenic (III) solution. To 20 g of arsenic (III) oxide (BDH AR) and 50 g sodium chloride (Aldrich, 99.999% pure), 400 cm^3 of 2.5 M sulphuric acid was slowly added. Deionized water was added to increase the volume to about 1 dm^3. The mixture was heated gently until all the solids had dissolved. The solution was cooled to room temperature, diluted to 2 dm^3, filtered and stored in a dark bottle at room temperature away from light.

Cerium (IV) solution. Ceric ammonium sulphate (48 g; associated chemicals AR) was dissolved in 800 cm^3 of 1.75 M sulphuric acid, cooled to room temperature and the volume made up to 1 dm^3. The solution was stored in a dark bottle away from light at room temperature.

Standard iodine solution. Potassium iodate (168.5 mg; Associated Chemicals AR) was dissolved in deionized water to make a 100 cm^3 solution (1000 $\mu g I\, cm^{-3}$). This solution was used to prepare a 100 $\mu g I\, cm^{-3}$ solution which was in turn used to prepare the working standards: 20, 50, 100, 150 $\mu g I\, dm^{-3}$. Deionized water was used in all dilutions.

Procedure

The urine was removed from the freezer several hours before analysis and allowed to attain room temperature. The urine was shaken and 0.25 cm^3 of the urine was pipetted into a 13 $\times$ 100 mm test tube. Deionized water (0.25 cm^3) and each standard iodine solution were in turn pipetted into 13 $\times$ 100 mm test tubes, 0.75 cm^3 of chloric acid was added to each test tube and the tubes were then heated for 60 min in a heating block at 110°C in a fume hood. After cooling to room temperature, 3.5 cm^3 of the arsenic (III) solution was added to each tube, mixed and allowed to stand for 15 min; 0.35 cm^3 of the cerium (IV) solution was added to each tube. A time interval of exactly 20 s between each tube was maintained. Exactly 20 min after addition of the cerium (IV) to the first tube its absorbance at 405 nm was read using a Pye Unicam UV – visible spectrophotometer. Absorbances of successive tubes were read at 20 s intervals.

Results and discussion

The absorbances of blank and standard solutions were used to plot a calibration curve using the linear least squares method. The linear least squares equation and the absorbances were used to

Table 1. Median and mean urinary iodine concentrations ± standard deviation (SD) for each school and the percentage of the samples with urinary iodine concentration below the indicated level

School	*Number of samples*	*Median conc.* ($\mu g\ dm^{-3}$)	*Mean Conc.* ± *SD* ($\mu g\ dm^{-3}$)	$\leq 20\ \mu g\ ds^{-3}$	$\leq 50\ \mu g\ dm^{-3}$	$\leq 100\ \mu\ dm^{-3}$
Bhalekane	40	101	107 ± 62	5	25	48
Elangeni	40	66.9	77.3 ± 64	23	40	65
Endlozini	41	117	120 ± 62	5	20	39
Mbabane L.	38	124	116 ± 61	11	13	34
Mphumalanga	40	133	109 ± 71	18	30	43
Mpofu	40	145	160 ± 131	13	21	35
Ngonini	39	70.2	89.2 ± 65	21	33	56
Phophonyane	40	94.9	96.1 ± 67	10	35	50
St. Amadeus	40	125	125 ± 71	8	20	45
Zamani	41	70.6	78.1 ± 5.3	15	34	63
Region	399	102	108 ± 77	13	27	48

calculate the concentration of iodine in each sample. The mean iodine concentration for each school was then calculated. These values are given in Table 1. The median concentration of each school is also given in Table 1.

A mean concentration greater than 100 μgI dm^{-3} urine indicates that the population is not iodine deficient and hence is not at risk of IDDs (Dunn *et al.* 1993). The data in Table 1 shows four schools as being mildly iodine deficient. However, as suggested by Bourdoux (1988), mean concentrations tend to obscure recognition of iodine deficiency in part of the population if the group is heterogeneous in iodine intake. Bourdoux recommends that urinary iodine data be grouped to show samples with concentration (a) below 20 μgI dm^{-3}, (b) below 50 μgI dm^{-3} and (c) below 100 μgI dm^{-3}. This grouping is also given in Table 1. It is now apparent that there is substantial iodine deficiency in part of the population of most of the schools. In five schools at least 30% of the samples have at least moderate ($\leq$50 μgI dm^{-3}) iodine deficiency. Elangeni and Ngonini have 23% and 21% of the population respectively with severe deficiency ($\leq$20 μgI dm^{-3}). For the region as whole, 13% of the population suffers from severe deficiency whilst 27% has moderate deficiency and almost half the population (48%) suffers from at least mild deficiency.

The results given here show an increase in the median urinary iodine concentration when compared to Todd's results. Todd (1993) reported a median urinary iodine concentration of 12.08 μgI dm^{-3} for the Hhohho region compared to 107 μgI dm^{-3} reported here. This improvement maybe attributed to the salt iodization program which was implemented soon after the Todd report.

The Hhohho region can be divided into three distinct physiographic regions, the lowveld, middleveld and highveld. The elevation, median slope and annual rainfall for each of these regions are given in Table 2. The mean urinary iodine concentration for each physiographic region is also given in the same table. The concentration decreases from 134 μgI dm^{-3} in the lowveld to 97 μgI dm^{-3} in the highveld. The difference in mean concentrations between lowveld and middleveld is statistically significant whilst that between middleveld and highveld is not statistically significant (using the Student *t*-test at 95% confidence level). The observed trend is

Table 2. Geomorphological parameters, mean annual rainfall and mean urinary iodine concentration for the three physiographic regions of the Hhohho region.

Region	*Elevation** (m)	*Median slope*[a] *(%)*	*Mean annual rainfall*[b] *(cm)*	*Mean conc.* ($\mu g\ dm^{-3}$)
Lowveld	90–370	3	50–90	134
Middleveld	330–1070	12	75–115	107
Highveld	>1200	18	100–230	97

Data from [a]Murdoch (1970) and [b]Fakudze (1996).

what is expected on the basis of the elevation, high median slope and high rainfall of the highveld which make the region susceptible to iodine deficient soils due to leaching.

Conclusion

The data presented in this paper show that there is still substantial iodine deficiency in the Hhohho region of Swaziland. Close to half the population is at risk of at least mild IDDs whilst 13% of the population is at risk of severe IDDs. The highveld of the Hhohho region is more at risk of IDDs than the middleveld and lowveld.

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