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ORIGINAL PAPER

# Medical geology of endemic goiter in Kalutara, Sri Lanka; distribution and possible causes

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**Abstract** This study assesses the distribution of goiter in the Kalutara District, Sri Lanka in order to find causative factors for the occurrence of goiter even after the salt iodization. A questionnaire survey was conducted at the household level and at the same time iodine and selenium levels of the water sources were analyzed. Questionnaire survey results indicated the highest numbers of goiter patients in the northern part where the lowest were found in the southern sector which may be due to the presence of acid sulfate soils. Females were more susceptible and it even showed a transmittance between generations. Average iodine concentrations in subsurface water of goiter endemic regions are $28.25 \pm 15.47$ µg/L whereas non-goiter regions show identical values at $24.74 \pm 18.29$ µg/L. Surface water exhibited relatively high values at $30.87 \pm 16.13$ µg/L. Endemic goiter was reported in some isolated patches where iodine and selenium concentrations low, latter was <10 µg/L. The formation of acid sulfate soils in the marshy lands in Kalutara district may lead to transformation of biological available iodine oxidation into volatile iodine by humic substances, at the same time organic matter rich peaty soil may have strong held of iodine and selenium which again induced by low pH and high temperature were suggested as the instrumental factors in the endemic goiter in Kalutara district. Hence, geochemical features such as soil pH, organic matter

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and thick lateritic cap in the Kalutara goiter endemic area play a role in controlling the available selenium and iodine for food chain through plant uptake and in water.

**Keywords** Iodide · Acid sulfate soils · Laterite · Selenium · Salt iodization · Soil organic matter

## Introduction

It has been estimated that almost one third of the world's population lives in areas with iodine deficiency (Zimmermann 2009). Iodine is an essential element for mammals as a component of the hormones produced by the thyroid gland. Diet is the sole source of iodine, which depends upon the iodine concentrations present in water and soil. The history of iodine and its importance have been discussed in the literature (Zimmermann 2009; Shetaya et al. 2012). After the first global estimate from the World Health Organization (WHO) in 1980, the prevalence of goiter was reported with an estimate of 20–60% of the world's population was iodine deficient where the developing world was influenced most (WHO 2014). Even after the salt iodine fortification program, iodine deficiency diseases (IDDs) still counted as a serious worldwide health problem in developing countries, estimated to affect ~35% (estimated as 2 billion) of the world's population (Zou et al. 2012; Pandav et al. 2013; WHO 2004; Zimmermann 2009). Goiter prophylaxis was first introduced in Switzerland and the United States by salt iodization in the early 1920s (Leung et al. 2012). Strengthening monitoring and evaluation of IDD and ensuring sustainability of IDD control activities are essential to achieve sustainable elimination of IDD.

Daily intake of iodine is being considered as 500 µg per individual whereas daily physiological requirement during adult life is 150 µg (Khurana 2006). Iodide, most commonly available inorganic form for plant and soil, is widely but unevenly distributed in the earth's environment due to depletion by leaching from glaciations, flooding, and erosion and hence, most iodide is found in the oceans, which is about 50 µg/L (Zimmermann 2009). Iodine cycling in many regions is slow and incomplete, leaving soils and drinking water iodine depleted (Dissanayake et al. 1999). Crops grown in these soils will be low in iodine, and humans and animals consuming food grown in these soils become iodine deficient. Iodine concentrations in plants grown in deficient soils are 100 times lower in dry weight, compared to the plants from iodine-sufficient soils (Zimmermann 2009).

Although Sri Lanka is a small island (65,600 km$^2$) in the Indian Ocean, endemic goiter has been reported in Sri Lanka for the past 50 years (Dissanayake et al. 1999). The pattern of endemic goiter in Sri Lanka closely follows the climate-topographic regions of Sri Lanka. First studies on epidemiology of goiters in Sri Lanka was formerly studied by Mahadeva and Senthe Shanmuganathan (1967) who proposed an endemic goiter belt encompassing the wet zone and the parts of central hills. Subsequently, researches related to IDD in Sri Lanka revealed widespread prevalence with pockets in the wet zone (Fernando et al. 1989, 2012; Dissanayake and Chandrajith 1999; Chandrasinghe et al. 2015). Soil to plant transfer factor for iodine in rice is poor compared to green leafy vegetables and hence iodine in rice are often very low compared to soil and to other crops. Therefore, rice does not constitute a significant source of iodine in Sri Lankan diet (Fordyce et al. 2000). Previous studies reported that Kalutara District, adjacent to the Indian Ocean in the south west of Sri Lanka has the highest endemic goiter patients (Fordyce et al. 2000; Dissanayake and Chandrajith 1999), which was suggested as multifactorial, involving trace element deficiencies such as selenium and other factors such as poor nutrition and goitrogens in foodstuffs (Dissanayake et al. 1999). Most recent study on goiter prevalence in Sri Lanka exhibited to be different from earlier proposed patterns (Fernando et al. 2015). Comprehensive epidemiological map of goiters demonstrated the absence of an endemic goiter belt in the wet zone as proposed earlier however, no detail investigations have been conducted afterwards subsequent to the iodine fortification in order to see the distribution in Kalutara district and assess the causative factor for the endemic goiter. Hence, the objectives of this study were to provide social and genetic information about the occurrences of endemic goitre of the Kalutara District, detail investigations for goiter occurrence and finally to find the causative factor/s for unusual high rates of goitre distribution in the Kalutara district, Sri Lanka.

## Materials and methods

### Questionnaire survey

The questionnaire survey was carried out in the thirteen District Secretariat (DS) divisions of the Kalutara District. A questionnaire survey was carried out at the beginning of the research to determine the distribution of goitre in the Kalutara District. The survey addressed mainly the following factors; (a) the drinking water source of the respondents, frequency of consuming sea foods, (b) most vulnerable group, (c) number of relatives in a family having goitre, (d) use of iodized salt and (e) present situation of the disease. As the research addresses the distribution of goitre within the Kalutara District, the respondents who were selected have been residing in the area for more than 2 decades. Over three hundred (300) were interviewed and among them 115 goitre patients.

### Water sampling

One hundred and sixteen (116) water samples were collected from running and stagnant water bodies in the area for chemical analyses. Dug wells, tube wells, rivers, streams, lakes, springs and marshy lands were the water sources for iodine (Fig. 1). Among the sources, dug wells, tube wells and springs were considered as subsurface water sources while other sources are surface waters. Several water samples were taken from selected lakes and rivers at different depths and locations. In dug wells, the depths were noted and the representative samples were taken. To compare the iodine level of the water, sampling was carried out both in water sources of goitre positive and negative areas.

The samples were taken after 1 month of continuous complete dry periods after rain. The water samples for iodine analysis were collected in brown coloured bottles. The bottles were completely sealed using a lid soon after filling and also did not allow exposure to sunlight. The total number of samples collected for analysis of iodine and selenium were 74 and 42 respectively. The dissolved Iodine in the water was analyzed by Photometric method (Greenburg et al. 1992). A 10 mL of water sample was taken and regents were added to the sample in following order: 1.00 mL NaCl solution, 0.50 mL Arsenious acid solution and 0.50 mL conc $H_2SO_4$. The reaction mixture and the Ceric ammonium sulphate solutions were placed in the 30 °C water bath and allowed to attain the equilibrium temperature. One milliliter of Ceric ammonium sulphate was added and after 15 ± 0.1 min, the sample was removed from the water bath. Then 1.00 mL of ferrous ammonium sulphate was immediately added while mixing, whereupon the yellow ceric ion colour was disappeared. Then 1 mL of potassium thiocyanate solution was added and the sample was replaced in the water bath. Within 1 h after thiocyanate addition, the colour was identified by a spectrophotometer—(wavelengths of 525 nm). Selenium was analyzed by the continuous hydride generator and atomic absorption spectrophotometer, Varion AA240 (Pettine et al. 2015).

## Results and discussion

### Study area

Kalutara is a second order administrative division situated in the Western Province of the country. The total land area is 1598 $km^2$ including 22 $km^2$ inland water areas. The entire district consists of 14 divisional secretariats. Kalutara District is located in the wet climatic region of the country. The wet zone comprises the southwestern part of Sri Lanka where 50% of the year consists of rainfall varying from 2280 to 5100 mm/year (Panabokke 1996).

The drainage network is mainly maintained by the Kalu Ganga and Bentara Ganga. There are several large and medium scale lakes such as Bolgoda Lake, Walgama wewa, Uyanwatta wewa, Wewita wewa, Gammanpila wewa etc. Bolgoda, presumed to be the largest natural lake in Sri Lanka, covers almost two thirds of the Kalutara district, extending from Anguruwatota to Piliyandala (Kalutara 1990). It is also the largest fresh water lake in Sri Lanka. Towards the west part flat terrain is observed and isolated low mountains are seen towards eastern part. The area is underlain by high-grade metamorphic rocks and thick lateritic caps. Holocence deposits such as thick alluvial plains and marshy lands are prominent (Kalutara 2013).

Most of the study area and the vicinity are covered by paddy fields, water logged marshy lands, small water canals and the majority was abandoned. Peaty

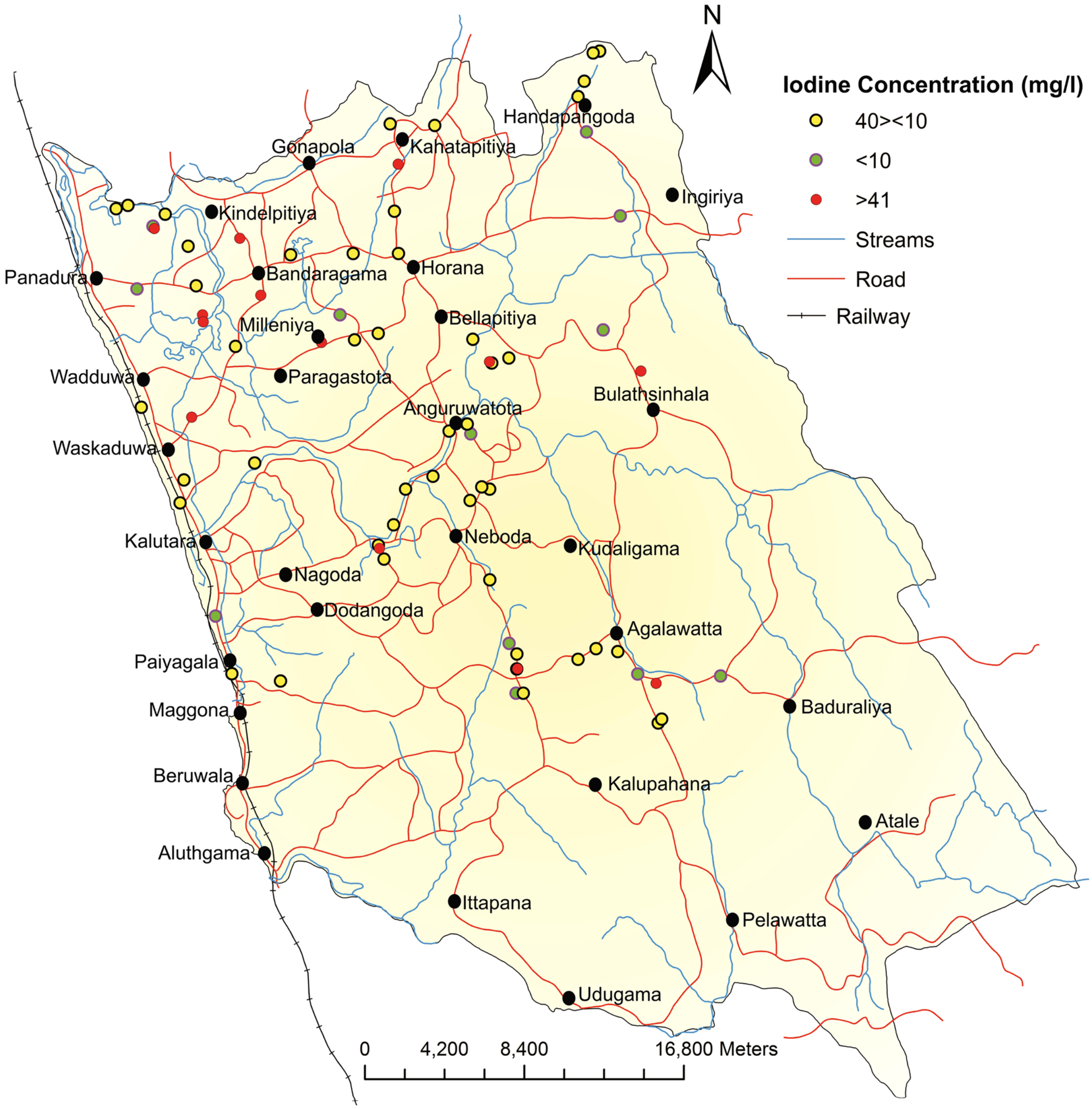


**Fig. 1** Sampling location and iodine concentration map for the study, Kalutara district, Sri Lanka

soil layers were clearly seen in soil cuts at various depths and disposed peat masses and abandoned paddy fields shown in Fig. 2.

Questionnaire survey data

During the field visit, 115 goitre affected people were found. Some of them are as older as 75 years whereas some are as younger as 16 years of age. Drinking water source of most of the people living in Kalutara district is dug wells, which accounts 97.4% of the total population of the surveyed areas. The depths of the dug wells varied from 2 to 18 m.

Number of goitre patients found in thirteen Divisional Secretaries (DS) divisions of the Kalutara District are shown in Fig. 3. The highest numbers of goitre patients were reported from northern sector of the district; Bandaragama, Ingiriya and Horana DS

**Fig. 2** Paddy fields in the study area and black peat layers observed at one of the excavation sites of the southern highway

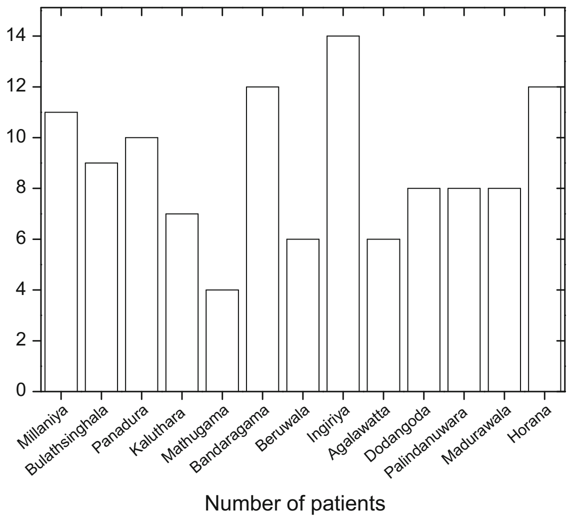


**Fig. 3** Goitre patients found in different Divisional Secretariat Divisions of Kalutara

divisions whereas the lowest goitre patient were found from Matugama, Beruwala and Agalawatta DS divisions. Interestingly, Bandaragama, Ingiriya and Horana DS divisions are located in the northern part of the Kalutara district and associated river is Kalu Ganga. Catchment of Bentara Ganga is seen in the southern sector of the Kalutara district, where lowest number of Goitre patients was reported (Fig. 3).

Over 300 males and females were interviewed and recorded in the questionnaire survey in the Kalutara district and revealed that 89% of goitre affected patients were females. It is an obvious fact that the women are having problems with thyroid 3–10 times more, than the men (Truong et al. 2005; Malboosbaf et al. 2013). The thyroid gland syntheses thyroid hormones that is responsible for many of the complex metabolic processes in the body. It has been identified that the effects of female gonadal hormones; prolactin and estrogen and X chromosome inactivation on thyroid gland and immune system greatly contribute to the IDD in female. At the same time the direct actions of estrogen on the thyroid tissue contribute to the development of thyroid goiter (Li and Li 2015).

Pregnant women are the most sensitive to iodine deficiency, as during this period the woman's hormonal system undergoes serious challenge. Besides, by 16th–17th week the fetus begins to develop its own thyroid gland, and it begins to take iodine from mother. During the field survey, it was revealed that there were 108 incidents that had been transmitted between one, two, three and four generations. It was also revealed that 75.5% of the total surveyed goitre patients are transmitted to a next generation (Fig. 4). Out of these, forty five (45) incidents were from one generation to the next whereas six incidents (6) transmitted goitre to two generations. However, it must be noted that only 17% of the goiter patients are having hormonal therapy while 100% are using iodine fortified salt.

It is very clear that, there were 45 incidents that transmitted from mother to daughter and 6 incidents from grandmother, mother to daughter and also one incident from great grandmother, grandmother, mother to daughter (Fig. 4). Only one case, it was found that goitre transmitted from mother to her son. The rarest case was that of two families where all family members including parents had goitre. There were only 12 males that were found to be goitre positive. There was one incident that within a same family, all 5 daughters have goitre except 2 sons. Therefore, it is clear that males are less prone to the disease and also transmission in generations also less compared to females. The symptom appearing period of the affected people indicated that it occurs mostly in the mid ages, 30–40 years, and only a few cases were found where the symptoms occur at the teenage duration. Few incidents reported that signs of goitre appeared in the age of forty or above.

## Concentrations of iodine

Iodine concentrations of dug well (shallow groundwater) samples and its frequency distribution are


**Fig. 4** Few goiter patients from different parts of the Kalutara District, Sri Lanka

presented in Fig. 5. Frequency distributions of iodine concentrations of water samples collected from dug wells where high and low incidence of goiter are shown in Figs. 5a, b respectively. Thirty two (32) samples from shallow wells in regions of goitre patients show the average concentration of 28.25 ± 15.47 μg/L whereas iodine concentration of nineteen (19) samples from non-goitre regions show similar but slightly low values at 24.74 ± 18.29 μg/L. It is noteworthy that about 97.4% of people consume water for drinking purposes are from dug wells and it appears that iodine concentration of shallow groundwater are above the critical iodine concentration in most part of the Kalutara district, however the large number of goiter incidents indicate the need of revision for the critical iodine concentration.

Iodine concentrations of surface water showed relatively higher values at 30.87 ± 16.13 μg/L. Iodine concentrations of natural springs, which are considered as confined aquifers, show high values between 28 and 35 μg/L. However, water samples collected from tap water, tube wells and marshy lands show low values for iodine (Table 1). This study reveals that iodine concentrations are higher than 20 μg/L in many places sampled irrespective of source of water. However, iodine concentrations in surface water are the highest among the water sources. Iodine concentrations in different locations are shown in a location map to show the variation of iodine with geographic location. There is no significant relationship of iodine concentrations in water and reported goiter patients during field survey.

However, some isolated patches can be observed in some places with low iodine concentrations less than 10 μg/L, especially in Ingiriya, Horana and Bandaragama DS divisions where high goiter patients were reported. The three DS divisions mentioned above are considered as main alluvial plain of the Kalu Ganga. In case of iodine in Kalutara district, iodine concentrations were reported to vary within the

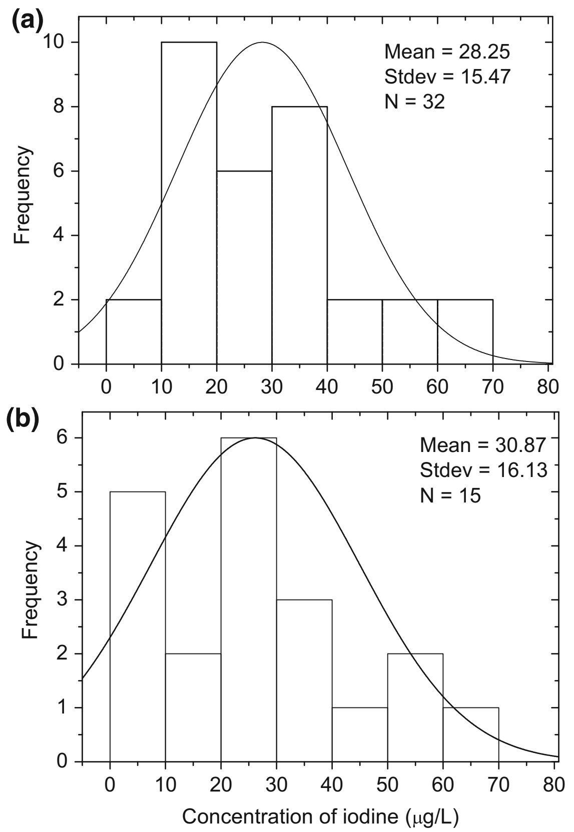


**Fig. 5** **a** Frequency distribution of iodine in Dug wells with high incidence for goitre and **b** Frequency distribution of iodine in dug wells with low incidence for goitre

different water sources. We observed that the coincidence of lower iodine content with high incidence of goitre patients in the Ingiriya, Horana and Bandaragama DS divisions however, it is not significant. Iodine contents of water by other studies in Sri Lanka are compared with our study (Table 2).

According to the guidelines for drinking water quality, third edition by World Health Organization, estimates of the dietary requirement of iodine for adult humans range from 80 to 150 mg/day (WHO 2004). According to the section 12.73 of WHO regulations, it says that derivation of a guideline value for iodine on the basis of information on the effects of iodine is inappropriate, and there are few relevant data on the effects of iodine. Because iodine is not recommended for long term disinfection, lifetime exposure to iodine concentrations such as might occur from water disinfection is unlikely. For these reasons, a guideline value for iodine has not been established.

According to Table 2, iodine concentrations in waters from the dry zone (e.g. Polonnaruwa) are distinctly higher that the iodine in the wet and intermediate zone reported by other investigators. However, our study shows that iodine contents in Kalutara district is somewhat unique with isolated patches of low values, which coincide with some high goitre incidents are reported. This suggests that although iodine is considered as an essential constituent for the development of goitre, iodine cannot alone considered as the main factor for goitre problem reported in Sri Lanka. Some other factors may also effect for the function of thyroid gland.

## Selenium

Although selenium accumulates in acid sulfate soils, soil organic matter removes selenium from soil solution as a result of fixation by organometallic complexes (Fordyce 2013). Organic matter rich soils in Kalutara area may immobilize selenium in the soil and thereby low or no selenium concentrations are to be found in water. Soil organic matter is the dominant control of soil selenium (Fordyce 2013). Relatively low values of selenium in entire Kalutara district may control the $T_4$–$T_3$ transformation, which prevents the thyroid metabolism and may leads to goitre problems in Kalutara district. The dietary requirement of selenium is revised as 70 μg/day for men and 60 μg/day for women in Germany (Kipp et al. 2015). Coexistent selenium deficiency increases thyroid-stimulating hormone (TSH) levels in severely iodine-deficient areas thereby subsequently contributing to the development of goiter (Brauer et al. 2006). Hence, it can also exist as a causative factor for IDD prevalence in the endemic region. A study from Fordyce et al. (2000) shows that significant proportion of females (24–40%) in Sri Lanka is deficient in selenium in their hair samples. This observation coincides with the observation from the present study on 89% of goitre incidents in Kalutara district are female population. Overall, selenium concentrations were quite low in the study area, which may play a major role in endemic goiter.

## Effect of acid sulfate soils

Another factor considered to be important in understanding the iodine geochemistry is the acidity of soil

**Table 1** Iodine and selenium concentration distribution in Kalutara

| Sample no | DS division | Depth (m) | Source | Iodine concentration in µg/L | Selenium concentration in µg/L | Goitre patients | Remarks |
|---|---|---|---|---|---|---|---|
| 1 | Bulathsinghala | 0.3 | Surface water | 23 | <1 | | Kalu Ganga |
| 2 | Bulathsinghala | 5.4 | Dug well | 62 | <1 | Yes | |
| 3 | Bulathsinhala | NA | Tube wells | 20 | <1 | | |
| 4 | Agalawatta | 4.8 | Dug well | 16 | <1 | Yes | |
| 5 | Palindanuwara | 2.5 | Dug wells | 47 | <1 | | |
| 6 | Palindanuwara | 3.6 | Dug wells | 37 | <1 | | |
| 7 | Palindanuwara | 0.6 | Surface water | <1 | <1 | | Stream |
| 8 | Agalawatta | 1.5 | Dug wells | 25 | <1 | | |
| 9 | Mathugama | 7.9 | Dug well | 38 | <1 | Yes | |
| 10 | Mathugama | Surface | Surface water | 28 | <1 | | Stream |
| 11 | Madurawala | 7.3 | Dug well | 35 | 2 | Yes | |
| 12 | Madurawala | 0.3 | Surface water | 14 | <1 | | Kalu Ganga |
| 13 | Dodamgoda | 4.8 | Dug well | 26 | <1 | Yes | |
| 14 | Dodamgoda | 1 | Surface water | 31 | <1 | | Kalu Ganga |
| 15 | Horana | 4.6 | Dug well | 37 | <1 | Yes | |
| 16 | Horana | 0.6 | Surface water | 47 | <1 | | Stream |
| 17 | Horana | 3.9 | Dug well | 25 | <1 | Yes | |
| 18 | Horana | 4.3 | Dug well | 12 | 2 | Yes | |
| 19 | Ingiriya | 2 | Dug well | 9 | 5 | Yes | |
| 20 | Ingriya | 0.3 | Surface water | 31 | <1 | | Mawak Oya |
| 21 | Ingiriya | 3.9 | Dug well | 24 | <1 | Yes | |
| 22 | Ingiriya | 6.1 | Dug well | 28 | <1 | Yes | |
| 23 | Millaniya | 4.6 | Dug well | 17 | 1 | Yes | |
| 24 | Millaniya | 2 | Dug well | 14 | <1 | Yes | |
| 25 | Millaniya | 1.8 | Dug well | 46 | <1 | Yes | |
| 26 | Millaniya | 6.1 | Dug well | 40 | 2 | Yes | |
| 27 | Bandaragama | 1.5 | Surface water | 40 | <1 | | Uyanwatta Wewa |
| 28 | Bandaragama | 6.4 | Dug well | 50 | <1 | Yes | |
| 29 | Bandaragama | 0.6 | Surface water | 53 | <1 | | Bolgoda Ganga-Mahabellana |
| 30 | Kalutara | 0.15 | Marshy lands | 27 | <1 | | |
| 31 | Kalutara | 4 | Dug wells | 62 | <1 | | |
| 32 | Kalutara | 5.8 | Dug well | 26 | 1 | Yes | |
| 33 | Kalutara | 4.6 | Dug wells | 25 | 7 | | |
| 34 | Kalutara | NA | Tap water | 0 | 1 | | |
| 35 | Beruwala | 4.8 | Dug well | 17 | <1 | Yes | |
| 36 | Beruwala | 8.5 | Dug well | 31 | <1 | Yes | |
| 37 | Panadura | 0.3 | Surface water | 40 | <1 | | Bolgoda Ganga-Hirana |
| 38 | Panadura | 2.1 | Dug well | 27 | <1 | Yes | |
| 39 | Panadura | 18.6 | Dug well | 61 | <1 | Yes | |
| 40 | Bandaragama | 5.2 | Dug wells | 21 | <1 | | |

**Table 2** Iodine and selenium contents in different water bodies in Sri Lanka

| Area | Iodine concentration (μg/L) | References |
|---|---|---|
| Anuradhapura (surface water) | 53.0–84.0 | Fordyce et al. (2000) |
| Kandy (surface water | 15–150 | Dissanayake & Chandrajith (1993) |
| Kandy/Kalutara (surface water) | 3.3–23.5 | Fordyce et al. (2000) |
| Matale | 11.1–16.91 | Balasuriya et al. (1992) |
| Polonnaruwa | 33.0–47.2 | Balasuriya et al. (1992) |
| Colombo | 11.4–16.9 | Balasuriya et al. (1992) |
| Gampaha | 5–11.9 | Balasuriya et al. (1992) |
| Kalutara (dug wells) | 9.0–62.0 | This study |
| Kalutara (surface water) | 0.0–53.0 | This study |

and water bodies. The influence of pH in the on the iodine form and mobility in relation to IDD has been extensively reported in the work of Fuge and Johnson (1986), Fuge (1996) summarize that the Eh–pH conditions govern the form and mobility of iodine in soil. Under acidic-oxidizing conditions, unbound iodine in soil is present as iodide may volatilize to $I_2$ and converse effect happens at alkaline conditions where iodine is immobilized as stable iodate. In acidic-reducing conditions iodine is stable as iodide.

In case of Kalutara district, it is reported that the area is underlain by Holocene deposits with an abundance of marshy lands, estuaries, salt marshes, wetlands, lagoons, iron rich laterite and acid sulfate soil etc. Acid sulfate soil (ASS) deposits rich in peaty layers are very frequently found in coastal low lying areas in the Kalutara district commonly below 5 m above the mean sea level (Jayasinghe 2009; IEE 2011). Although peaty soils are enriched in iodine, organic matter is considered as a main contributor for iodine retention (Fuge 1986). Simultaneously, aluminum and iron oxides play a major role in iodine retention (Fuge and Johnson 1986). Hence, peaty and acid sulfate soils may have strongly held iodine and selenium in organic forms hence, not sufficiently available to enter into the food chain.

## Consumption of goitrogens

Inadequate iodine intake and inadequate iodine utilization are the two major factors affecting IDD. The inadequate iodine intake is considered as secondary to low iodine content of the soil and consequently the endemic population consumes food with low iodine availability. On the other hand the presence of goitrogens in certain foods may lead to inadequate iodine utilization (Ahad and Ganie 2010). Mahadeva and Senthe Shanmuganathan (1967) measured the iodine content and the amount of different food stuffs consumed by rural population in Sri Lanka and estimated that the daily intake of iodine per person per day was 300–350 μg in wet zone. The selenium and iodine provided by rice alone fall well below the recommended daily intake of these elements. According to the Rice Research and Development Institution in Sri Lanka, red rice cultivation is concentrated in a few districts of Sri Lanka and is found in two areas (Kalutara and Galle) with relatively high goitre incidence rates (Fordyce et al. 2000). Red rice is considered as a goitrogen (Fordyce et al. 2000) and could exacerbate the goiter conditions. Also, foods such as cabbage, and members of the cruciferaceae are considered as goitrogens (Dissanayake and Chandrajith 1999). Hence, consumption of red rice and other goitrogen foods may also stimulate the goiter incidents.

The average of symptom appearing period of the affected people is identified as mid ages, after 35 years. Although some incidences reported that symptoms appeared in early ages below 20 years, symptoms that appeared in more than sixty cases are in the age range of 21–39 years. If the relevant authorities can take measures to increase the iodine and selenium levels at their younger ages, a long term solution could be given to avoid the goitre problem in the Kalutara district.

## Conclusions

Endemic goitre is a serious health problem in some coastal parts of in Sri Lanka, Kalutara, even after the salt iodine fortification program. A study has been made of a goitre population living in the Kalutara district in the southwest Sri Lanka. In the areas studied in the Kalutara district, although iodine deficiency was identified as the principal etiologic factor for goitre distribution, no correlation between iodine in water and goitre distribution was identified. However, selenium levels of the water are low and none of the samples exceeded the desired limit of 10 μg/L. The difference in iodine contents of drinking water in case of goitre and controls is minimal. It has been noted that the soils of Kalutara inherently high in organic matter, acid sulfates, iron and aluminum rich laterites hence, and selenium bioavailability is minimal which controls the amount of selenium uptake through food chain. Some pockets have low iodine concentrations where there were significant goiter incidents however, no significant influence was observed from iodine in water to patients with goiter. Consumption of red rice and other goitrogens may reduce iodine concentrations in the body further aggravate the condition.

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