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STATUS IODIUM ANAK USIA SEKOLAH DAN SEBARAN IODIUM, MERKURI, TIMBAL DALAM TANAH DAN AIR DI DAERAH PERBUKITAN ENDEMIK GOITER, PONOROGO

Iodine Status in School Children and Distribution of Iodine, Mercury, Lead in Soil and Water in The Endemic Goiter Hill Area, Ponorogo

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ABSTRACT

Background. *Iodine deficiency disorders (IDD) remained a public health problem. Ponorogo was an IDD endemic area with prominent cases of mental retardation. Despite the lack of iodine intake, exposure to environmental heavy metals can exacerbate the effects of iodine deficiency.* ***Objective.*** *To describe iodine status of school children and distribution of environmental iodine and heavy metals including mercury (Hg), lead (Pb), and cadmium (Cd) in the endemic IDD hill area of Ponorogo.* ***Method.*** *This research is a cross-sectional study conducted in two villages in IDD endemic areas in Ponorogo, namely Dayakan and Watubonang villages, in 2011. A total of 127 urine samples of primary-school-age children were taken and analyzed for urinary iodine excretion (UIE). A total of 29 soil samples and 87 water samples were taken from the study site to measure the concentration of iodine and heavy metals Hg, Pb, and Cd. Types of water source, altitude, and land use, both soil and water source were recorded.* ***Results.*** *The median (min-max) UIE was 130 (14 –1187 µg/L) within the range of adequate population iodine intake according to WHO (100-199 µg/L), while the percentage of UIE <100 µg/L was still around 33.07 percent. The concentration of iodine in the soil was 33.777 mg/kg (6.640 –108.809), and the concentration of iodine in the water was 8.0 µg/L (0-49). The concentration of Hg in the soil was 68.64 ppb (7.43–562.05), and the concentration of Hg in the water was 0.00 ppb (0.00-23.24). The concentration of Pb in the soil was 3.273 ppm (0.000–25.227), while Pb was not identified in the water. The Cadmium was not detectable both in the soil and water.* ***Conclusion.*** *Iodine deficiency is still a public health problem in Dayakan and Watubonang villages. The environment of the endemic IDD area in Ponorogo was not completely poor in iodine, but iodine was not evenly spread and mobilized. There was a risk of environmental heavy metal exposure from Hg in the soil or water and Pb in the soil. Mercury in the environment can cause health problems due to the inhibition of the use of iodine in the thyroid gland.*

Keywords: *IDD, iodine, lead, mercury, UIE*

ABSTRAK

Latar Belakang. Gangguan akibat kekurangan iodium (GAKI) masih menjadi masalah kesehatan masyarakat. Kabupaten Ponorogo merupakan daerah endemik GAKI dengan kasus keterbelakangan mental yang menonjol. Selain kekurangan asupan iodium, pajanan cemaran logam berat lingkungan dapat memperburuk dampak kekurangan iodium. **Tujuan.** Mengetahui gambaran status iodium anak usia sekolah, distribusi iodium logam berat merkuri (Hg), timbal (Pb), dan kadmium (Cd) di daerah perbukitan endemik GAKI, Kabupaten Ponorogo. **Metode**. Penelitian ini merupakan studi potong lintang yang dilakukan di dua desa di wilayah endemik GAKI di Kabupaten Ponorogo, yaitu Desa Dayakan dan Watubonang pada tahun 2011. Sejumlah

127 sampel urine anak usia sekolah diambil dan dianalisa kadar ekskresi iodium urine (EIU). Sebanyak 29 sampel tanah dan 87 sampel air diambil dari lokasi penelitian untuk pengukuran konsentrasi iodium dan logam berat Hg, Pb, dan Cd. Jenis sumber air, ketinggian tempat, dan penggunaan lahan dari sumber air dan tanah dicatat. **Hasil.** Median (min-maks) EIU adalah 130 (14–1187 µg/L) berada dalam kisaran asupan iodium populasi yang cukup menurut WHO (100–199 µg/L), dengan persentase EIU<100 µg/L sekitar 33,07 persen. Konsentrasi iodium dalam tanah 33,777 mg/kg dan konsentrasi iodium dalam air 8,0 µg/L. Konsentrasi Hg dalam tanah 68,64 ppb dan konsentrasi Hg dalam air 0,00 ppb. Konsentrasi Pb dalam tanah 3,273 ppm dan tidak teridentifikasi Pb dalam air. Sedangkan Cd tidak teridentifikasi baik dalam tanah maupun air. **Kesimpulan.** Kekurangan iodium masih menjadi masalah kesehatan masyarakat di Desa Dayakan dan Watubonang. Lingkungan daerah endemis GAKI di Kabupaten Ponorogo tidak sepenuhnya miskin iodium, tetapi iodium tidak tersebar dan termobilisasi secara merata. Ada risiko paparan logam berat lingkungan dari Hg baik di tanah atau air maupun Pb di dalam tanah. Merkuri di lingkungan berpotensi menimbulkan gangguan kesehatan akibat penghambatan penggunaan iodium pada kelenjar tiroid.

Kata kunci: GAKI, iodium, timbal, merkuri, EIU

INTRODUCTION

Iodine deficiency was one of the major global public health problems. Iodine deficiency produces a spectrum of abnormalities, such as goiter and cretinism, hypothyroidism, decreased fertility rate, increased perinatal death, infant mortality, and impaired neurocognitive development.[1] These all spectrum were grouped under the heading of iodine deficiency disorders (IDD), which reflect thyroid dysfunction.[2] Iodine deficiency may be aggravated by the intake of natural goitrogens[3] and exacerbated by deficiencies of selenium[4] iron[5] and vitamin A and protein energy.[6] Iodine deficiency disorders in a geographic area were primarily caused by low iodine content of the soil, water, or crops.[7]

Epidemiological observations suggest that environmental factors significantly effect the settlement and development of new IDD cases in endemic areas.[8] Low iodine content of the environment is a primary cause of IDD. Food and water produced in an iodine-poor environment would not provide enough iodine for human needs.[9] Mountainous areas and inland areas generally were poor iodine environment, that in its, IDD generally occurred.[10] However, IDD was also found in coastal areas and islands, where the materials goitrogenic, blocking agents, and genetic factors played a role in these conditions.[11,12] The presence of heavy metals in the environment was related to the incidence of endemic goiter in many cases. Mercury (Hg), lead (Pb), and cadmium (Cd) are known as toxic materials to the organism.[13] Heavy metals often contaminate drinking water from shallow water. Heavy metals are known to inhibit the use of iodine in the thyroid gland.[12,14,15,16] In Ponorogo, IDD was an endemic health problem. In 1998, the total goiter rate (TGR) in this regency was 23.9 percent, with the highest was in the Badegan district with TGR 60.1 percent.[17] In 2009, the prevalence of IDD in Ponorogo was 12.27 percent.[18] IDD-prone villages remained in Ponorogo with many cases, such as goiter, cretinism, and mental function disorders.[19]

The presence of IDD in Ponorogo was often associated with calcareous soil that spread out in the broad area. So, it is difficult for the population to cultivate other staple food sources other than cassava, known as goitrogenic sources.[20] However, in the calcareous soil environment, high calcium and magnesium were known as goitrogenic. In soil, calcium and magnesium bound iodine firmly to mobilize to the food chain and in the body via ingestion of food or drinking water; these interfered with absorption of iodine.[21]

In another IDD endemic area, Wonogiri, which nearly has the same geographical conditions as Ponorogo, it reported that IDD problems in this area were still serious, with an IDD prevalence of 21.1 percent.[22] This study aimed to describe iodine status in school children and the distribution of iodine and heavy metals Hg, Pb, and Cd in soil-water in the endemic goiter hill area Ponorogo.

METHODS

A cross-sectional study has been conducted in 2 severe endemic areas of IDD in limestone hills Ponorogo, namely Dayakan and Watubonang villages in Badegan district. The research location was determined purposively by the Health Office of Ponorogo regency. It was also based on its location in Badegan District, a severe endemic area of IDD[17], and located in the limestone hills.

A total of 127 urine samples of primary school-aged children range from 6 to 12 years of age were taken at school in Agustus 2011 and analyzed for UIE levels. A total of 29 soil samples and 87 water samples were taken from the study site to measure the concentration of iodine and heavy metals Hg and Pb. It was determined soil sampling locations in the study area through a uniform grid method with a distance of 1.5 kilometers. At each location point, approximately 1 kg soil is taken from a depth of approximately 20 cm. It took 50 mL of groundwater samples from all water sources used by residents in the research location as a source of drinking water. The spectrophotometer method based on the Sandell-Kholtoff reaction analyzed UIE and iodine water and soil content. It used atomic absorption spectrophotometer (AAS) method to analyze Hg, Pb, and Cd concentrations both in soil and water. UIE and iodine water concentration were analyzed in Research and Development Center Magelang. The concentration of Hg, Pb, and Cd in soil, water, and iodine soil was conducted in Integrated Research and Testing Laboratory-Gadjah Mada University (LPPT-UGM) and Center for Environmental Health Engineering and Disease Control (BTKLPP), Yogyakarta.

The UIE data was calculated and categorized based on the epidemiological criteria for the assessing of iodine nutrition intake based on the median urine iodine concentration for school-age children.[1] Iodine and heavy metal content data were categorized based on the altitude and surrounding land use, while water was grouped based on the water source. The difference test between each category through Mann-Whitney Test.

RESULT

Urinary Iodine Excretion (UIE)

Urinary iodine excretion of school-age children ranged from 14 to 1187 μg/L with a median of 130 μg/L. Based on epidemiologic criteria for assessing iodine nutrition based on median urinary iodine concentrations, median urinary iodine at 100–199 μg/L,[1] there was no deficiency of iodine intake in population level in our study. But there was 33.07 percent of the children had a risk of iodine deficiency (Table 1).

Table 1. Urinary Iodine Excretion (UIE) of School-Age Children in Dayakan and Watubonang Villages, Ponorogo

Category of UIE (μg/L)	n	Percentage (%)	Total Median UIE (Min-Max)
<50	2	1.57	130 μg/L (14–1187)
50–99	40	31.50	
100–199	60	47.24	
>200	25	19.69	
Total	127	100.00	

Environmental Iodine

A wide range of iodine concentrations in soil was detected, from 6.640 mg/kg to 108.809 mg/kg with a median of 33.777 mg/kg. Broad range content of iodine is also found in each altitude range and also each land use. The soil in altitude less than 250 masl contained iodine 51.965 mg/kg, significantly higher than soil in altitude 250–500 masl that contained 15.702 mg/kg and altitude more than 500 masl that contained 26.509 mg/kg. Soil iodine content in settlement area was 51.965 mg/kg, irrigated rice field 48.643 mg/kg, dryland farming 9.876 mg/kg, bush 41.159 mg/kg and forrest 35.278 mg/kg. There was a significant difference in soil iodine concentration between settlement areas and dryland farming (Table 2).

Iodine concentration in water of study site area ranged from 0 μg/L (undetectable) to 49 μg/L with a median of 8.00 μg/L. Water from dug/shallow wells contained iodine 8 μg/L in concentration, significantly higher than water from spring that contained 0 μg/L. Water from the water source in altitude less than 250 masl contain iodine 12 μg/L in concentration, that significantly higher than in altitude 250–500 masl that contain iodine 0 μg/L and also altitude more than 500 masl that also contain iodine 0 μg/L. Iodine concentration in water from a water source in altitude less than 250 masl was 12 μg/L that significantly higher than its concentration in altitude 250–500 masl and also altitude more than 500 masl with iodine concentration in both were 0 μg/L. Iodine concentration in water from a water source in the settlement area was 13 μg/L, while in the rainfed rice field was 5 μg/L, dryland farming and the bush was 0 μg/L. There was a significant difference in water iodine concentration in land use, except between dryland farming and bush (Table 2).

Table 2. Soil and Water Iodine Concentration in Dayakan and Watubonang Villages, Ponorogo

	n	Median (min-max)	p Mann-Whitney
Soil iodine concentration			
Altitude			
<250 masl[a]	9	51.965 mg/kg (36.778–100.209)	p(a:b)=0.021; p(a:c)=0.007;
250–500 masl[b]	13	15.702 mg/kg (7.010–108.809)	p(b:c)=0.843
>500 masl[c]	7	26.509 mg/kg (6.640–44.617)	
Landuse			
Settlement area[d]	5	51.965 mg/kg (39.961–60.988)	p(d:e)=1.000; p(d:f)= 0.008;
Irrigated rice field[e]	2	48.643 mg/kg (41.934–55.352)	p(d:g)=0.347; p(d:h)=0.361;
Dry land farming[f]	11	9.876 mg/kg (6.604–58.676)	p(e:f)=0.076; p(e:g)=0.439;
Bush[g]	5	41.159 mg/kg (9.653–108.809)	p(e:h)=0.505; p(f:g)=0.100;
Forest[h]	6	35.278 mg/kg (7.604–108.809)	p(f:h)=0.070; p(g:h)=0.855
Total	29	33.777 mg/kg (6.640–108.809)	
Water iodine concentration			
Type of Water Sources			
Spring[i]	15	0.0 μg/L (0–5)	p(i:j)=0.001
Dugg/shallow wells[j]	72	10.5 μg/L (0–49)	
Altitude			
<250 masl[k]	67	12 μg/L (0–49)	p(k:l)=0.001; p(k:m)=0.001;
250–500 masl[l]	11	0 μg/L (0–1)	p(l:m)=0.366
>500 masl[m]	9	0 μg/L (0–0)	
Landuse			
Settlement[n]	60	13 μg/L (0–49)	p(n:o)=0.043; p(n:p)=0.001;
Rainfed rice field[o]	9	5 μg/L (0–40)	p(n:q)=0.007; p(o:p)=0.001;
Dry land[p]	15	0 μg/L (0–0.9)	p(o:q)=0.023; p(p:q)=0.655
Bush[q]	3	0 μg/L	
Total	87	8.00 μg/L (0–49)	

masl: meter above sea level

Environmental Mercury (Hg)

Soil Hg concentration in the study area ranged from 7.43 to 562.05 ppb with a median of 68.64 ppb. Mercury concentration in soil at an altitude less than 250 masl contained Hg in concentration 73.66 ppb, altitude 250–500 masl contained 63.32 ppb, and altitude more than 500 masl contained 76.45 ppb. There were no significant differences in soil Hg concentration between altitudes. The soil in the settlement area contained iodine in concentration 99.70 ppb, while Hg concentration in irrigated rice field was 58.56 ppb, dryland farming was 74.94 ppb, the bush was 36.41 ppb, and the forest was 59.80 ppb. There was no significant difference in soil Hg concentration in land use (Table 3). Water Hg concentration in the study area ranged from 0.00 to 23.24 ppb with median 0.00 ppb. Mercury concentration in water from spring contained 0.29 ppb which was significantly different water from dug/shallow wells that contained 0.00 ppb (p=0.048). Water from water source at altitude less than 250 masl contained Hg 0.00 ppb, at altitude 250–500 masl contained Hg 0.56 ppb and more than 500 masl contained 0.28 ppb. There was a significant difference in Hg water concentration between altitudes less than 250 masl and 250–500 masl. Water from the water source in land use settlement, rainfed rice field, dryland farming, and bush contained Hg 0.00 ppb, 0.00 ppb, 0.28 ppb, and 0.76 ppb, respectively. There was a significant difference in water Hg concentration in land use between settlement area and bush (Table 3).

Table 3. Soil and Water Mercury (Hg) Concentration (ppb) in Dayakan and Watubonang Villages, Ponorogo

	n	Median (min-max)	p Mann-Whitney
Soil Hg concentration			
Altitude			
<250 masl[a]	9	73.66 (22.25–562.05)	p(a:b)=0.483; pa:c)=0.560;
250–500 masl[b]	13	63.32 (10.42–255.16)	p(b:c)=0.968
>500 masl[c]	7	76.45 (7.43–296.04)	
Landuse			
Settlement area[d]	5	99.70 (55.22–562.05)	p(d:e)=0.245; p(d:f)= 0.336;
Irrigated rice field[e]	2	58.560 (55.71–61.41)	p(d:g)=0.117; p(d:h)=0.144;
Dry land farming[f]	11	74.940 (7.43–296.04)	p(e:f)=0.430; p(e:g)=0.699;
Bush[g]	5	36.41 (10.42–123.00)	p(e:h)=0.739; p(f:g)=0.462;
Forest[h]	6	59.80 (21.15–125.40)	p(f:h)=0.615; p(g:h)=0.715
Total	29	68.64 (7.43–562.05)	
Water Hg concentration			
Type of Water Sources			
Spring[i]	15	0.29 (0.00–4.91)	p(i:j)=0.048
Dugg/shallow wells[j]	72	0.00 (0.00–23.24)	
Altitude			
<250 masl[k]	67	0.00 (0.00–23.24)	p(k:l)=0.048; p(k:m)=0.341;
250–500 masl[l]	11	0.56 (0.00–4.91)	p(l:m)=0.332
>500 masl[m]	9	0.28 (0.00–1.69)	
Landuse			
Settlement[n]	60	0.00 (0.00–23.24)	p(n:o)=0.983; p(n:p)=0.129;
Rainfed rice field[o]	9	0.00 (0.00–1.61)	p(n:q)=0.045; p(o:p)=0.464;
Dry land[p]	15	0.28 (0.00–4.91)	p(o:q)=0.139; p(p:q)=0.117
Bush[q]	3	0.76 (0.56–1.78)	
Total	87	0.00 (0.00–23.24)	

masl: meter above sea level; ppb: parts per billion

Environmental Lead (Pb) Concentration

Soil Pb concentration in the study area ranged from 0 to 25.227 ppm with a median of 3.273 ppm. The soil in altitude lower than 250 masl contained Pb about 8.907 ppm, altitude 250–500 masl contained 3.051 ppm, and altitude more than 500 masl contained 2.967 ppm. It found a significant difference in soil Pb concentration between an altitude of less than 250 masl and an altitude of 250–500 masl (p=0.007). In a settlement, soil Pb concentration was 4.635 ppm, irrigated rice field was 11.062 ppm, dryland farming was 3.182 ppm, the bush was 2.967 ppm, and the forest was 5.423 ppm. Within lands, there was a significant difference of soil Pb concentration only between settlement area and bush (p=0.028) (Table 4). There was no detectable Pb concentration in the water of all water from all sources in the study area.

Table 4. Soil Lead (Pb) Concentration (ppm) in Study Area Dayakan and Watubonang Villages, Ponorogo

	n	Median	p Mann-Whitney
Altitude			
<250 masl[a]	9	8.907 (2.974–19.536)	p(a:b)=0.007; p(a:c)=0.153;
250–500 masl[b]	13	3.051 (0.000–16.803)	p(b:c)=0.599
>500 masl[c]	7	2.967 (0.000–25.227)	
Landuse			
Settlement area[d]	5	4.635 (2.974–8.956)	p(d:e)=0.563; p(d:f)= 0.458;
Irrigated rice field[e]	2	11.062 (10.556–11.567)	p(d:g)=0.028; p(d:h)=0.855;
Dry land farming[f]	11	3.182 (0.000–25.227)	p(e:f)=0.161; p(e:g)=0.053;
Bush[g]	5	2.967 (0.000–3.109)	p(e:h)=0.180; p(f:g)=0.455;
Forest[h]	6	5.423 (0.000–19.536)	p(f:h)=0.758; p(g:h)=0.269
Total	29	3.273 (0.000–25.227)	

masl: meter above sea level; ppm: parts per million

Environmental Cadmium (Cd) Concentration

Cadmium was not detectable in soil and water in an endemic area in Dayakan and Watubonang villages.

DISCUSSION

This study emphasizes the level of environmental iodine and some heavy metals in the study site and their distribution. It measured the population's iodine intake status to determine the condition of iodine adequacy at the study time. Iodine deficiency disorders are a significant global public health problem, one of the world's major causes of preventable cognitive impairment, and threaten countries' social and economic development. This motivated people worldwide to eliminate IDD.[1] Based on UIE in Dayakan and Watubonang Villages, the lack of iodine intake in the population level at the endemic hill area of IDD was not found. Although the median UIE in Dayakan and Watubonang is adequate based on the epidemiological criteria for assessing iodine nutrition based on median urinary iodine concentrations of school-age children, iodine deficiency is still a public health problem in Dayakan and Watubonang villages, of which 33.07 percent of the children in this study at risk for iodine deficiency. In Dayakan and Watubonang villages, Ponorogo, it did not find any lack of iodine intake in the endemic area of IDD. Most of the epidemiological IDD studies had emphasized rapid, inexpensive urinary iodine determination methods that could apply to many samples. All iodine in the blood is in the iodide form, either taken up by the thyroid and converted into thyroid hormone or excreted in the urine. Almost 90 percent of the ingested iodine is excreted in the urine. Therefore, urinary iodine excretion is a promising biomarker of very recent dietary iodine intake.[9]

This study found that iodine was distributed in a wide range of concentrations both in soil and water. There was a tendency for iodine levels to decrease with the increase in altitude in both water and soil. It is was relevant with Musoddaq and Setyani, that found iodine concentration in groundwater on the western slopes of Mount Merapi decreased in line with the increased height of the water sources above sea level.[23] Based on the British Geological Survey, the soil was one of the most important sources of iodine in groundwater besides the aquifers and atmosphere.[24] Iodine in soil tended to be uniform in concentration among land use in this study. It contrasts with the concentration of iodine in water that was different between land uses where water sources were locating. Land use and human activity on it probably affected iodine released to water sources in it. Activities on land in such areas will modify the environment's ability to retain iodine.[25] Soil micronutrient availability were affected by land use and management. [26]

Drinking water iodine 5 µg/L or less was vulnerable for IDD.[24] This study showed that Ponorogo was not poor environmental iodine that many water sources were produced by water with iodine concentration that more than the vulnerable level of IDD. This study found that water with an iodine content of more than 5 µg/L was more often found in dugg/shallow wells, areas with an altitude of fewer than 250 meters above sea level, and residential areas. Overall, in Dayakan and Watubonang villages, Ponorogo, there was a magnitude of iodine reserves in the soil that could mobilize through water, which can be a source of iodine for the community. However, the incidence of IDD in the past showed that environmental iodine in Ponorogo regency could prevent the community from lack of iodine intake. It also might be caused by the inaccessibility of environmental iodine sources in endemic areas or others. Theoretically, in the environment, iodine in soil and water can enter the food chain and reach humans through the food and beverages consumed. However, environmental iodine is not always in a form that humans can consume, such as through food and drink, so that environmental iodine cannot enter the human body. In addition, environmental iodine may be present in the form of food or drink that humans can consume. However, sometimes iodine-rich foods such as fish, meat, and eggs from the local environment cannot be consumed because the price is relatively high. Many factors such as socio-economic might cause people cannot to access high price of iodine-rich food such as meat and eggs that are locally produced. Intake of natural goitrogens, deficiency of selenium, iron, vitamin A, and also protein-energy can cause IDD associated with impaired iodine metabolism. [3,4,5,6]

Heavy metals Hg, Pb, and Cd, are known as an environmental pollutants. Mercury is widespread in the environment and originates from natural and anthropogenic sources. This study shows that Hg concentration in soil and water varied widely and tended to be uniform among altitude and land use and water from different water sources. However it found water with high levels of Hg. There was no threshold for Hg concentration in soil. However, it was detected Hg concentration in water that exceeded the threshold for drinking water, sanitation, and hygiene. The Minister of Health of the Republic of Indonesia regulates the threshold of Hg in drinking water, sanitation, and hygiene were 0.001 ppb.[27,28] Mercury concentration in water more than 1 ppb could be found in many water source in all land use and not associated with altitude in this study. The presence of pollutant sources might cause the presence of water or soil with high levels of Hg.[29]

CONCLUSION

Iodine deficiency is still a public health problem in the villages of Dayakan and Watubonang. The environment of the endemic IDD area in Ponorogo was not completely poor in iodine, but iodine was not evenly spread and mobilized. There was a risk of environmental heavy metal exposure from Hg in the soil or water and Pb in the soil. Mercury in the environment can cause health problems due to the inhibition of the use of iodine in the thyroid gland.

SUGGESTION

It is necessary to prevent activities that can increase heavy metal contamination in an endemic area of Ponorogo, especially Hg and Pb.

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