Jurnal Mutu Pangan Vol. 9(1): 36-44, 2022
ISSN 2355-5017
DOI: 10.29244/jmpi.2022.9.1.36

Consumption of Drinking Water and Its Contribution to Lead (Pb) Exposure in Toddlers Nutritional Status in Indonesia

Konsumsi Air Minum dan Kontribusinya terhadap Paparan Timbal (Pb) pada Status Gizi Anak Balita di Indonesia

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Abstract. Stunting in toddlers is still occurring in Indonesia. Heavy metals, especially lead (Pb), can cause calcium metabolism disorders. Drinking water has the largest contribution to Pb exposure. The research objective was to conduct a risk assessment of Pb from drinking water in toddlers in Indonesia. The Pb risk assessment was carried out by testing Pb levels in drinking water, extracting consumption data from the Individual Food Consumption Survey in 2014 and Basic Health Research in 2013, calculating Pb exposure, characterizing Pb risk, and predicting the correlation of Pb exposure from drinking water to the toddler nutritional status based on length/height-for-age. The average Pb exposure ranged from 0.026-0.082 µg/kgbw/day and the margin of exposure value ranged from 28.05-8.79 thus the risk of Pb from drinking water for toddlers was low. Correlation value between Pb exposure and the toddler nutritional status based on length/height-for-age in provinces with Pb levels more than limit of detection for children aged 0-11, 12-23, 24-35 and 36-47 months was 0.004; -0.038; -0.109 and -0.231, respectively. The resulting correlation from 0.004 to -0.231 were weak therefore Pb exposure from drinking water is unlikely causing stunting in Indonesian toddlers.

Keywords: drinking water, exposure assessment, lead, stunting, toddler

Abstrak. *Kondisi stunting pada anak balita masih terjadi di Indonesia. Logam berat khususnya Timbal (Pb) dapat menyebabkan gangguan metabolisme kalsium. Air minum memiliki kontribusi terbesar terhadap paparan Pb. Tujuan penelitian adalah menentukan risiko konsumsi air minum yang mengandung Pb pada anak balita di Indonesia. Kajian risiko Pb dilakukan dengan menguji kadar Pb dari air minum, ekstraksi data konsumsi dari Survei Konsumsi Makanan Individu 2014 dan Riset Kesehatan Dasar 2013, menghitung paparan Pb, karakterisasi risiko Pb, dan memprediksi korelasi antara paparan Pb dari air minum dengan status gizi berdasarkan panjang badan atau tinggi badan menurut umur pada anak balita. Paparan timbal rata-rata berkisar antara 0.026-0.082 µg/kgbb/hari dan nilai Margin of Exposure berkisar antara 28.05-8.79, maka risiko Pb dari air minum pada anak balita adalah rendah. Nilai korelasi antara paparan Pb dan status gizi panjang badan atau tinggi badan menurut umur pada anak balita di provinsi dengan kadar Pb lebih dari LoD pada anak usia 0-11, 12-23, 24-35 dan 36-47 bulan secara berurutan adalah 0.004; -0.038; -0.109 and -0.231. Hasil korelasi antara 0.004 dan -0.231 yang lemah menunjukkan paparan Pb dari air minum tidak menyebabkan stunting pada anak balita di Indonesia.*

Kata Kunci*: air minum, balita, kajian paparan, stunting, timbal*

Practical Application: Lead (Pb) risk assessment from drinking water in toddlers can provide an overview of Pb risk for toddlers in Indonesia and a correlation between Pb exposure and toddler nutritional status based on length/height-for-age. The results of this research can be used by stakeholders dealing with stunting in Indonesia.

INTRODUCTION

Stunting is a toddler with short stature due to prolonged malnutrition (Candra 2013). Stunting or short conditions in children is a form of malnutrition due to the overall socioeconomic conditions limitation in the past (Cahyono *et al*. 2016). Stunting is not only due to malnutrition but also influenced by genetic factors, for example, parental height (Susetyowati *et al*. 2017). The nutritional status of a toddler is one of the indicators of community nutrition that has developed into welfare and health indicator (Harjatmo *et al*. 2018). The mother's level of knowledge affects the nutritional status of a toddler (Weya *et al*. 2018). In the first 1.000 days of a toddler's life, normal growth is a target which must be achieved (Reurings *et al*. 2013). The highest prevalence of stunting occurred in children aged 12 months (Bove *et al*. 2012). Toddlers who often suffer infectious diseases, such as malaria, respiratory tract infections, and diarrhea, tend to become stunted (Pacheco *et al*. 2017).

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Toddlers with a history of receiving non-exclusive breastfeeding have a 165 times higher risk of stunting than those with exclusive breastfeeding (Damayanti *et al*. 2016). Gender did not affect stunting conditions for toddlers (Anticona and Sebastian 2014). Stunting human resources have lower quality than normal human resources (Zilda and Sudiarti 2013).

Based on the Agency for Toxic Substances and Disease Registry, Pb is a heavy metal contaminant that affects stunting because it disrupts calcium metabolism for bone growth resulting non-optimal growth (ATSDR 2019). Stunted children had higher blood Pb levels at the age of 20–40 months (mean µg/dL [SD]: 6.2 [5.0] – 4.6 [4.1]) compared to children who did not stunt (Gleason *et al*. 2016). Stunting disrupts students thinking and learning abilities, and eventually, student attendance and learning achievement will be decrease compared to non-stunted children (Picauly and Toy 2013). Based on the Food Chemical Contamination Analysis conducted by the Ministry of Health in 2015, drinking water contributed to the highest exposure to Pb compared to other foods (MoH RI 2015).

Consuming drinking water containing over-limit Pb may have a health risk. Effective efforts to remove heavy metals in water are very important tasks to be completed by experts (Hua *et al*. 2012). It is necessary to conduct an exposure study and analysis of the correlation between Pb exposure and nutritional status using raw water samples from large food industries and food home industries that were taken to represent all provinces in Indonesia. Raw water taken from the food industry is groundwater or drinking water installations, which is also the water that is consumed the most in households based on Individual Food Consumption Survey in 2014. Based on the Ministry of Health data, raw water is consumed the most in households compared to branded bottled drinking water and bottled drinks (MoH RI 2014). Pb levels in drinking water were analyzed using the test method SNI 6989-46-2009 (Water and Wastewater – Part 46: Test method for lead (Pb) by Atomic Absorption Spectrophotometry (AAS) – carbon furnace) in an accredited laboratory. Data on drinking water consumption for toddlers in Indonesia were obtained from the Individual Food Consumption Survey in 2014 (MoH RI 2014). Pb risk characterization from drinking water obtained using the Margin of Exposure (MoE) approach with a Benchmark Dose Lower-bound (BMDL) value for children of 0.6 µg/kgbw/day, the value of chronic dietary exposure corresponding to a decrease 1 IQ point in children (Wang *et al.* 2019). However, limitation in this study, the same BMDL was used to determine Pb risk characterization from drinking water because there is no BMDL specifically for drinking water.

Nutritional status based on length/height-for-age is a standard based on length or height of children from the Ministry of Health for identifying children's nutritional status. The toddler nutritional status based on length/height-for-age can identify stunted toddlers, so toddlers are assessed as stunting if the toddler nutritional status based on length/height-for-age is <-2 SD (z-score) according to the Children's Anthropometric Standards by the Ministry of Health (MoH RI 2020). This study aimed to characterize the risk of Pb from drinking water and to estimate the correlation between toddler nutritional status based on length/height-for-age with Pb exposure from drinking water in Indonesia.

MATERIALS AND METHODS

Materials

The materials used were raw water from large food industries and food home industries from 34 provinces in the city/district with the largest population based on data from the Indonesian Central Statistics Authority (Table 1), except the bottled drinking water industry. The bottled drinking water industry is not included in the sampling location because the raw water used is usually pre-treated. Each sample was taken as much as 500 mL from groundwater or drinking water installations and the total sample was 68 samples.

The large food industry is an industry that larger than the home food industry or produces processed food with the MD registration number from the Indonesian FDA. The home food industry is an industry that produces processed food in residence or home with manual to semi-automatic processing equipment (Indonesian FDA 2018).

Sampling method using simple random sampling in which every member of the population has an equal chance of being selected as a sample (Arieska and Herdiani 2018). The percentage of the population from the city/district where the sample was taken compared to the total population in Indonesia in 2018 was 14.7%.

Secondary data was obtained from Individual Food Consumption Survey in 2014 and Basic Health Research in 2013 from the National Institute of Health Research and Development, Ministry of Health Republic of Indonesia.

Secondary data extraction

Secondary data of drinking water consumption, weight of children aged 0-47 months were obtained from Individual Food Consumption Survey in 2014 (MoH RI 2014), and toddler nutritional status based on length/height-for-age of the same subject/children were obtained from Basic Health Research in 2013 (MoH RI 2013). Drinking water consumption data were grouped by age groups 0-5 months, 6-11 months, 12-23 months, 24-35 months, and 36-47 months, and also grouped by percentile to obtain the data distribution.

Table 1. The city/district and the population of the sampling location

Province	City/District	Project Year	Total Population (Province)	Total Population (City/District)
Aceh	North Aceh District	2016	5,096,248	593,492
North Sumatra	Medan City	2017	14,262,147	2,247,425
West Sumatra	Padang City	2015	5,196,289	902,413
Riau	Pekanbaru City	2018	6,717,612	1,101,706
Riau Archipelago	Batam City	2017	2,082,694	1,283,196
Jambi	Jambi City	2018	3,570,272	598,103
Bengkulu	Bengkulu City	2013	1,814,357	334,529
South Sumatra	Palembang City	2018	8,391,489	1,651,857
Bangka Belitung Archipelago	Bangka District	2018	1,459,873	330,793
Lampung	Central Lampung District	2017	8,289,577	1,261,498
Banten	Tangerang District	2017	12,448,160	3,584,770
West Java	Bogor District	2016	47,379,389	5,587,390
DKI Jakarta	East Jakarta Administrative City	2015	10,177,924	2,843,816
Central Java	Brebes District	2018	34,490,835	1,802,829
East Java	Surabaya City	2017	39,292,972	2,874,699
DI Yogyakarta	Sleman District	2016	3,720,912	1,180,479
Bali	Denpasar City	2018	4,292,200	930,600
West Nusatenggara	East Lombok District	2017	4,955,578	1,183,204
East Nusatenggara	South Central Timor District	2018	5,371,519	465,970
West Kalimantan	Pontianak City	2017	4,932,499	627,021
South Kalimantan	Banjarmasin City	2018	4,182,695	700,869
Central Kalimantan	East Kotawaringin District	2018	2,660,209	456,409
East Kalimantan	Samarinda City	2018	3,573,804	837,573
North Kalimantan	Tarakan City	2017	691,058	253,026
Gorontalo	Gorontalo District	2017	1,168,190	374,923
South Sulawesi	Makassar City	2014	8,432,163	1,429,242
Southeast Sulawesi	Kendari City	2017	2,602,389	370,728
Central Sulawesi	Parigi Moutong District	2018	3,010,440	482,790
North Sulawesi	Manado City	2017	2,461,028	430,133
West Sulawesi	Polewali Mandar District	2017	1,130,960	432,690
Maluku	Ambon City	2018	1,773,776	461,699
North Maluku	South Halmahera District	2017	1,209,342	227,280
Papua	Jayapura City	2018	3,322,526	297,775
West Papua	Sorong City	2018	937,458	247,084
		Total	261,098,584	38,388,011

Source: Indonesian Central Statistics Authority

Concentration of Pb in drinking water determination (NSA RI 2009)

Pb levels were tested in the accredited laboratory using Graphite Furnace Atomic Absorption Spectrometry (GF-AAS) with the Limit of Detection (LoD) of 0.001 mg/L and a Limit of Quantification (LoQ) of 0.003 mg/L with the test method of SNI 6989-46-2009 (Water and Wastewater – Section 46: Test Method for Lead (Pb) by Atomic Absorption Spectrophotometry (AAS) – carbon furnace) (NSA RI 2009). Each province obtained 2 levels of Pb originating from large food industries and home food industry then averaged using the lowerbound and upperbound value.

Pb exposure assessment from drinking water (WHO 2009)

The Pb exposure from drinking water was obtained by calculating data on the lowerbound and upperbound Pb levels, drinking water consumption, body weight of children aged 0-47 months, and grouped by percentile 95 and 97.5. The exposure calculation formula is as follows:

$$\text{Pb exposure (mg/kgbw/day)} = \frac{\sum \text{water consumption } (\frac{\text{liter}}{\text{day}}) \times \sum \text{Pb level } (\frac{\text{mg}}{\text{liter}})}{\text{weight (kg)}} \quad \ldots\ldots\ldots (1)$$

Pb risk characterization from drinking water (EFSA 2010; Wang *et al.* 2019)

Since the provisional tolerable weekly intake (PTWI) of lead was withdrawn, the EFSA recommends using MOE in determining risk characterization (EFSA 2010). Individuals with an MoE value of less than 1 have a high health risk, while an MoE of more than 1 had a low health risk (Juric *et al*. 2018). The formula for calculating MoE is:

$$\text{Margin of exposure} = \frac{\text{Benchmark Dose Lowerbound (µg/kgbw/day)}}{\text{Pb exposure (µg/kgbw/day)}} \quad \ldots\ldots\ldots\ldots (2)$$

Correlation of Pb exposure to the toddler nutritional status based on length/height-for-age (Schober *et al.* 2018)

Correlation of Pb exposure to the toddler nutritional status was calculated by Pearson Correlation analysis using 2 variables: Pb exposure from drinking water and nutritional status based on length/height-for-age, α value was 5%. Analysis was carried out based on age groups 0-5 months, 6-11 months, 12-23 months, 24-35 months, and 36-47 months, and based on provincial groups with Pb levels <Lod and Pb levels >Lod.

RESULTS AND DISCUSSION

Profile of drinking water consumption and nutritional status

Based on Table 2, it is known that the percentage of children in Indonesia not consuming enough drinking water aged 0-5 months, 6-11 months, 12-23 months, 24-35 months, and 36-47 months was 44.01, 63.54, 94.13, 93.56, and 88.81%. The average percentage of children aged 0-47 months not consuming enough drinking water according to the WHO standard was 76.81% (Grandjean 2004). Children who are dehydrated experience memory loss and cause feelings of less happiness (Benton and Young 2015). Children aged 4-9 years in China consume mean 966 mL/day of water (Zhang *et al*. 2018). The average drinking water consumption in the United Kingdom for boys aged 4-9 years was mean (SD) 529(348) mL/day and for girls aged 4-9 years was mean (SD) 434 (297) mL/day (Guelinckx *et al*. 2015). The standard of drinking water adequacy in Australia for children aged 2-3 years and 4-8 years is 1.4 L/day and 1.6 L/day, respectively. The average consumption of drinking water in Australia for boys aged 2-3 years was mean (SD) 1.2(0.4) L/day and for boys aged 4-8 years was mean (SD) 1.5(0.4) L/day. The average consumption of drinking water in Australia for girls aged 2-3 years was mean (SD) 1.1(0.3) L/day and for girls aged 4-8 years was mean (SD) 1.3(0.3) L/day (Sui *et al*. 2016). In Indonesia, children's water consumption is more than in the United Kingdom but less than in China and Australia.

Data on the nutritional status of weight-for-age of boys and girls aged 0-47 months in Indonesia have shown that as many as 57 boys (2.83% of the total 2.013 children) weighed less than -2SD z-scores (underweight) and 38 girls (1.99% of the total 1.911 children) weighed less than -2SD z-scores (underweight) (Figure 1A and 1B). Underweight factors in children aged 24-59 months were child gender, underweight maternal nutrition, and high cigarette expenditure in Indonesia (Kurnianingtyas *et al*. 2021).

Data on the toddler nutritional status based on length/height-for-age are grouped into 3 categories: normal (-2SD to +3SD) as many as 2.452 children (62.49%), short (stunted) (-3SD to -2SD) as many as 796 children (20.29%) and very short (severely stunted) (<-3SD) as many as 676 children (17.22%) (Figure 2). The total data of children in this study was 3,924 children.

Concentration of Pb in drinking water

Based on 68 samples, there were 9 samples (13.2%) with Pb levels of more than LoD (0.001 mg/L) originating from 8 provinces: Bangka Belitung (home industry 0.003 mg/L), Jambi (large industry 0.002 mg /L), North Maluku (home industry 0.001 mg/L), West NusaTenggara (large and home industry 0.002 mg/L), Papua (large industry 0.002 mg/L), West Sulawesi (large industry 0.002 mg/L), Central Sulawesi (large industry 0.002 mg /L) and Southeast Sulawesi (home industry 0.01 mg/L). Another 59 samples (86.8%) had test results less than LoD from 25 provinces (Figure 3).

The average of Pb levels in lower bound and upper bound of provinces with Pb levels less than LoD, provinces with Pb levels more than LoD and all provinces was 0-0.001; 0.0016-0.0021; and 0.0004-0.0013 mg/L, respectively. Several studies showing Pb levels in drinking water from various provinces in Indonesia were 0.01 mg/L (Febriwani *et al*. 2019), <0.01 mg/L (Herman 2018), <0.001 mg/L (Kabuhung *et al*. 2013), and 0.0086 mg/L (Sukoasih *et al*. 2017).

Pb exposure assessment from drinking water

Pb exposure was calculated based on Pb levels obtained from 25 provinces where Pb levels less than LoD (75.8%) and 8 provinces where Pb levels more than LoD (24.2%). The average exposure of Pb from drinking water in children aged 0-11 months, 12-23 months, 24-35 months, and 36-47 months in Indonesia ranged from 0.031-0.099; 0.027–0.085; 0.024–0.076 and 0.023–0.073 µg/kgbw/day, respectively (Table 3). Based on the results, the older the toddlers, the less exposure to Pb. This may be due to increasing body weight but insufficient drinking water consumption when the children getting older.

The average Pb levels in 25 provinces with Pb levels less than LoD ranged from 0–0.001 mg/L. The highest average Pb exposure was in children aged 0-11 months, which was 0.079 µg/kgbw/day, while the lowest average Pb exposure was in children aged 36-47 months, which was 0.058 µg/kgbw/day.

Table 2. Average consumption of drinking water for 0-47 months of children in Indonesia (mL/day)

Age (months)	n	Drinking Water Consumption (mL/day)																	Standard of Consuming Mineral Water from WHO (mL/day)
		Average	Deviation Standard	Min	P5	P40	P45	P50	P55	P60	P65	P70	P75	P80	P85	P90	P95	Max	
0-5	284	791.06	354.51	204	282.25	**647.4**	709.51	753.53	804.38	870	919.38	962.5	1000	1130	1190.63	1315	1460	1635	700
6-11	384	728.86	327.67	208	251.18	600	645	700	740	**780**	817.88	875	940	1000	1080	1193.5	1372.5	1630	800
12-23	1074	787.23	292.65	278	369.38	675	705	746.75	791.63	825	883.75	940	995	1055	1125	**1220.13**	1315	1532	1300
24-35	1181	785.97	287.70	318	387.75	674.6	712.35	755	780	820	868.83	905	975	1030.72	1126.53	**1221.6**	1334.5	1529.5	1300
36-47	1001	856.78	318.61	336	400	720	760	800	841.4	900	955	1000	1060	1143.96	**1220**	1331.6	1480	1710	1700

Note: P=Percentile; n=total samples; Source: Ministry of Health Republic of Indonesia

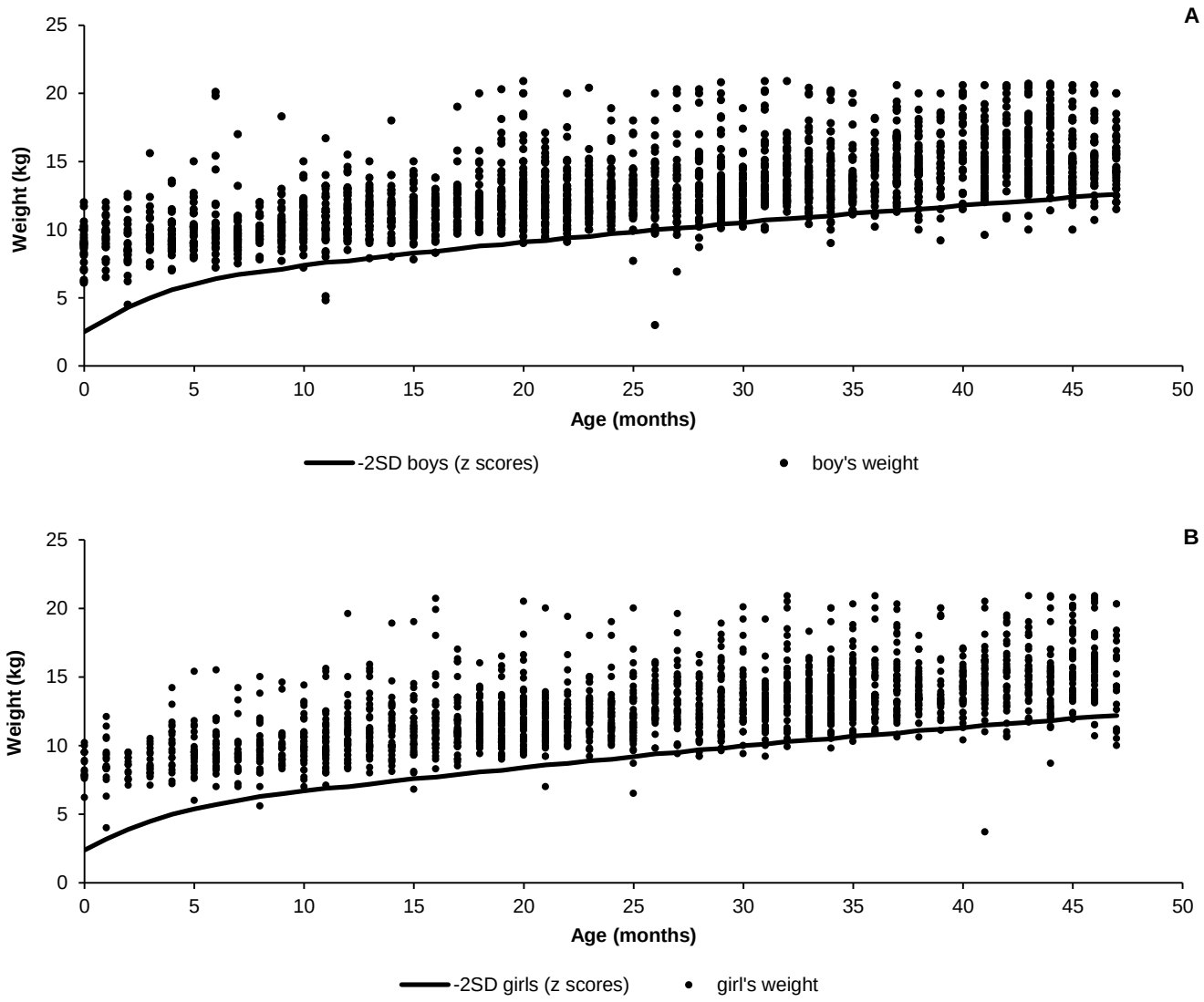

Figure 1. Graph of nutritional status of weight-for-age for boys aged 0-47 months (A) Graph of nutritional status of weight-for-age for girl aged 0-47 months (B)

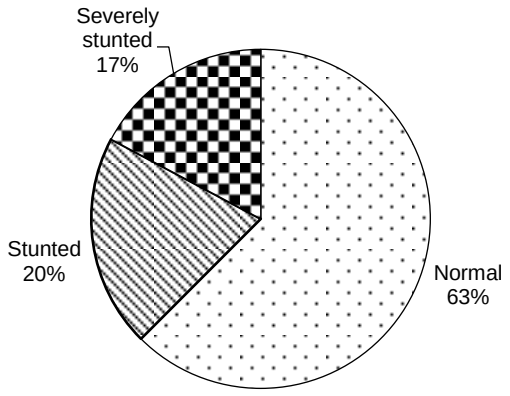

Figure 2. Percentage of nutritional status based on length/height-for-age for children aged 0-47 months

The highest average Pb exposure from 8 provinces with Pb levels more than LoD was in children aged 0-11 months ranging from 0.120-0.153 µg/kgbw/day, while the lowest average Pb exposure was in children aged 36-47 months ranging from 0.095-0.121 µg/kgbw/day. Pb exposure in children in 8 provinces with Pb levels more than LoD was higher than Pb exposure in 25 provinces with Pb levels less than LoD and the average of Pb exposure in all provinces.

The estimation of Pb exposure from drinking water in Food Chemical Contamination Analysis in 2015 children aged 0-35 months and 36-59 months was 0.526–1.707 and 0.553–1.923 µg/kgbw/day, respectively. Pb exposure in drinking water from Food Chemical Contamination Analysis in 2015 was higher than the results of this research, this was presumably due to different sampling techniques or methods. The water sample in the Food Chemical Contamination Analysis in 2015 is a national composite sample, thus the results of this research show more rational exposure data because Pb levels in drinking water from 33 provinces were included.

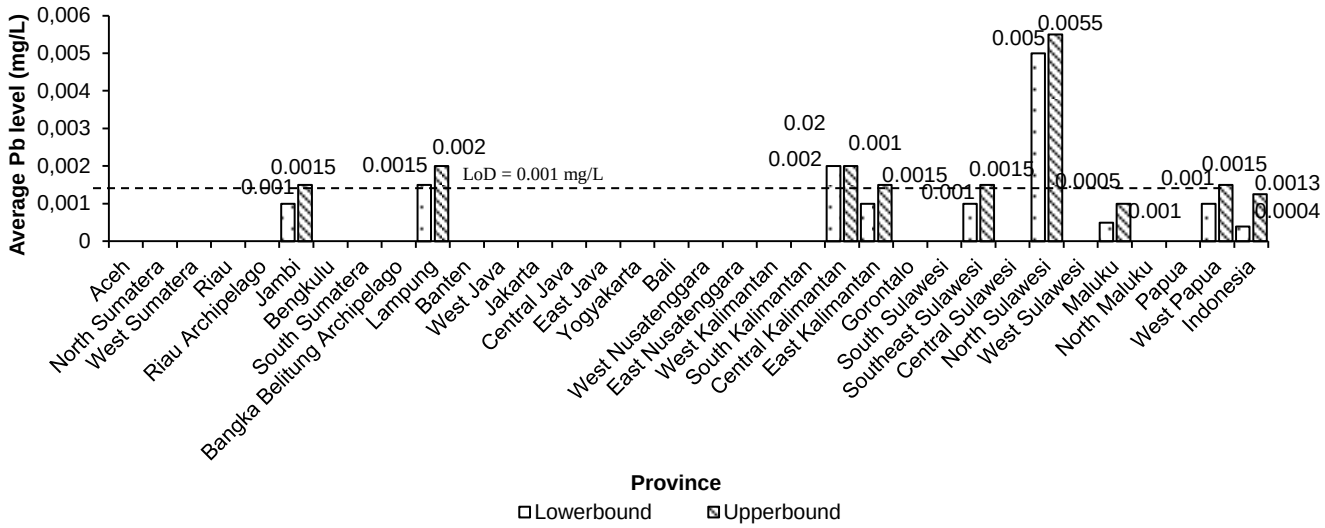

Figure 3. Average pb level of drinking water in provinces with pb levels more than LoD

Table 3. Level of Pb exposure from drinking water in children aged 0-47 months

Age (Months)		Pb Exposure (µg/kgbw/day)		
		25 Provinces with Pb <LoD	8 Provinces with Pb >LoD	Average Value in Indonesia
		Upper bound	Lower bound - Upper bound	Lower bound - Upper bound
0-11	Average	0.079	0.120 - 0.153	0.031 - 0.099
	St dev	0.037	0.057 - 0.073	0.014 - 0.046
	Min	0.015	0.036 - 0.046	0.006 - 0.019
	Max	0.208	0.290 - 0.368	0.082 - 0.261
	P95	0.149	0.245 - 0.311	0.058 - 0.186
	P97.5	0.163	0.274 - 0.348	0.064 - 0.205
12-23	Average	0.068	0.105 - 0.133	0.027 - 0.085
	St dev	0.026	0.044 - 0.056	0.010 0.033
	Min	0.019	0.034 - 0.043	0.008 - 0.024
	Max	0.169	0.234 - 0.297	0.066 - 0.212
	P95	0.116	0.193 - 0.246	0.046 - 0.146
	P97.5	0.128	0.200 - 0.254	0.050 - 0.160
24-35	Average	0.061	0.096 - 0.121	0.024 - 0.076
	St dev	0.024	0.039 - 0.049	0.009 - 0.030
	Min	0.018	0.031 - 0.039	0.007 - 0.022
	Max	0.255	0.243 - 0.309	0.100 - 0.321
	P95	0.106	0.172 - 0.218	0.042 - 0.133
	P97.5	0.113	0.197 - 0.250	0.044 - 0.142
36-47	Average	0.058	0.095 - 0.121	0.023 - 0.073
	St dev	0.022	0.040 - 0.051	0.009 - 0.028
	Min	0.017	0.038 - 0.048	0.007 - 0.021
	Max	0.133	0.245 - 0.311	0.059 - 0.190
	P95	0.100	0.172 - 0.219	0.040 - 0.127
	P97.5	0.110	0.185 - 0.235	0.043 - 0.138
0-47	Average	0.065	0.102 - 0.130	0.026 - 0.082
	St dev	0.028	0.045 - 0.057	0.011 - 0.035
	Min	0.015	0.031 - 0.039	0.006 - 0.019
	Max	0.255	0.290 - 0.368	0.100 - 0.321
	P95	0.116	0.188 - 0.239	0.046 - 0.146
	P97.5	0.131	0.211 - 0.268	0.052 - 0.165

Note: LoD=limit of detection; P=percentile

Pb risk characterization from drinking water

Pb risk characterization from drinking water using the MoE approach using a BMDL value for children of 0.6 µg/kgbw/day. The determination of Pb risk characterization carried out in the Guang Zhou region, People's Republic of China also used the MoE approach because the previous Provisional Tolerable Weekly Intake (PTWI) was withdrawn by WHO in 2011 (Wang *et al.* 2019).

The average value of MoE in Indonesia based on age groups 0-11 months, 12-23 months, 24-35 months, and 36-47 months ranged from 24.88-7.79; 26.38-8.26; 29.39-9.21 and 30.39-9.52, respectively. All age groups had an MoE value of more than 1 which means that the risk of Pb was low (Table 4). The risk is getting lower because when the children get older the less Pb exposure from drinking water.

Table 4. MoE value in children aged 0-47 months

Age (Months)		Margin of Exposure (MoE)		
		25 Provinces with Pb <LoD	8 Provinces with Pb >LoD	Average Value in Indonesia
		Upper bound	Lower bound - Upper bound	Lower bound - Upper bound
0-11	Average	9.73	6.23 - 4.91	24.88 - 7.79
	St dev	5.59	3.11 - 2.45	13.96 - 4.37
	Min	2.89	2.07 - 1.63	7.34 - 2.30
	Max	39.08	16.52 - 13.01	99.20 - 31.07
	P95	22.12	12.31 - 9.70	53.73 - 16.83
	P97.5	24.26	15.38 - 12.12	61.64 - 19.31
12-23	Average	10.27	6.82 - 5.38	26.38 - 8.26
	St dev	4.41	3.02 - 2.38	11.42 3.58
	Min	3.56	2.57 - 2.02	9.04 - 2.83
	Max	31.20	17.85 - 14.06	79.20 - 24.81
	P95	18.80	12.91 - 10.17	49.23 - 15.42
	P97.5	21.75	14.57 - 11.48	56.88 - 17.82
24-35	Average	11.50	7.36 - 5.80	29.39 - 9.21
	St dev	4.72	3.02 - 2.38	12.05 - 3.77
	Min	2.35	2.47 - 1.94	5.97 - 1.87
	Max	34.29	19.54 - 15.39	87.03 - 27.26
	P95	20.55	12.83 - 10.11	52.31 - 16.39
	P97.5	23.09	14.27 - 11.24	58.66 - 18.37
36-47	Average	11.95	7.46 - 5.88	30.39 - 9.52
	St dev	4.78	3.02 - 2.38	12.17 - 3.81
	Min	4.51	2.45 - 1.93	10.09 - 3.16
	Max	35.33	15.74 - 12.40	89.67 - 28.09
	P95	21.42	13.10 - 10.32	54.35 - 17.03
	P97.5	23.51	15.18 - 11.96	60.10 - 18.83
0-47	Average	10.98	7.04 - 5.54	28.05 - 8.79
	St dev	4.88	3.06 - 2.41	12.44 - 3.90
	Min	2.35	2.07 - 1.63	5.97 - 1.87
	Max	39.08	19.54 - 15.39	99.20 - 31.07
	P95	20.62	12.74 - 10.04	52.35 - 16.40
	P97.5	23.43	14.52 - 11.44	59.51 - 18.64

Note: LoD=limit of detection; P=percentile

The average value of MoE in 25 provinces with Pb levels less than LoD in children aged 0-11 months, 12-23 months, 24-35 months, and 36-47 months was 9.73; 10.27; 11.50 and 11.95, respectively. The resulting MoE value was higher in 0 months compared to 47 months, therefore it is likely that the older the children, the lower the risk of Pb from drinking water.

The average value of MoE in 8 provinces with Pb levels more than LoD in children aged 0-11 months, 12-23 months, 24-35 months, and 36-47 months ranged from 6.23-4.91; 6.82-5.38; 7.36-5.80 and 7.46-5.88, res-pectively. The older the children, the higher the average MoE value. The MoE values in 8 provinces were the lower compared to 25 provinces with Pb levels less than LoD and in all provinces.

Correlation of Pb exposure for nutritional status based on length/height-for-age

The toddler nutritional status based on length/ height-for-age was converted into numbers: severely stunted (1), stunted (2), and normal (3). Correlation analysis results (r-value) of Pb exposure on nutritional status in 8 provinces with Pb levels more than LoD in children aged 0-11 months, 12-23 months, 24-35 months, and 36-47 months was 0.004; -0.038; -0.109 and -0.231, respectively. From the results obtained, it can be seen that the correlation level of 8 provinces with Pb levels more than LoD is higher than 25 provinces with Pb levels less than LoD (Table 5).

Table 5. Correlation results between Pb exposure and nutritional status based on length/height-for-age in children aged 0-47 months

Age (months)	Pearson Correlation		
	25 Provinces with Pb <LoD	8 Provinces with Pb >LoD	Average Value in Indonesia
	Correlation (r)	Correlation (r)	Correlation (r)
0-11	0.027	0.004	0.027
12-23	-0.070	-0.038	-0.063
24-35	-0.030	-0.109	-0.043
36-47	-0.078	-0.231	-0.104

Note: LoD=limit of detection

The weak correlation between Pb exposure and nutritional status based on length/height-for-age may be due to other factors other than food and water safety, including consuming poor-quality food, consuming less breast milk or complementary feeding, and infection.

The theoretical implication of this research is that drinking water consumed by toddlers in Indonesia is unlikely causing stunting even though it contributes to the highest Pb exposure compared to other foods. The practical implication of this research is contributing to other research on Pb risk. It is recommended to use other parameters such as different types of water, environment, or time to obtain other results.

CONCLUSIONS

The average value of Pb exposure in drinking water in children aged 0-11 months, 12-23 months, 24-35 months, and 36-47 months ranged from 0.031-0.099; 0.027–0.085; 0.024–0.076 and 0.023–0.073 µg/kgbw/ day, respectively. Pb risk characterization with the average value of MoE obtained by age groups 0-11 months, 12-23 months, 24-35 months, and 36-47 months ranged from 24.88-7.79; 26.38-8.26; 29.39-9.21 and 30.39-9.52, respectively. All MoE value were more than 1, thus toddlers in Indonesia in all age groups had a low risk of Pb.

Provinces with Pb levels more than LoD had a stronger correlation between Pb exposure and nutritional status based on length/height-for-age compared to other provinces, with r values for children aged 0-11 months, 12-23 months, 24-35 months, and 36-47 months was 0.004; -0.038; -0.109 and -0.231, respectively. The resulting correlation from 0.004 to -0.231 were weak therefore Pb exposure from drinking water is unlikely causing stunting in Indonesian toddlers.

ACKNOWLEDGMENT

The authors would like to thank the Indonesian FDA for fund supporting this research.

REFERENCES

Anticona C, Sebastian MS. 2014. Anemia and malnutrition in indigenous children and adolescents of the peruvian amazon in a context of lead exposure: A cross-sectional study. Global Health Action 7(1): 22888. DOI: 10.3402/gha.v7.22888.

Arieska PK, Herdiani N. 2018. Pemilihan teknik sampling berdasarkan perhitungan efisiensi relatif. Statistika 6(2): 166-171.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2019. Toxicological Profile for Lead. ATSDR's Toxicol Profiles (May). DOI: 10.1201/9781420061888_ch106.

Benton D, Young HA. 2015. Do small differences in hydration status affect mood and mental performance? Nutr Rev 73(S2): 83-96. DOI: 10.1093/nutrit/nuv045.

Bove I, Miranda T, Campoy C, Uauy R, Napol M. 2012. Stunting, overweight and child development impair-ment go hand in hand as key problems of early infancy: Uruguayan case. Early Hum Dev 88(9): 747-751. DOI: 10.1016/j.earlhumdev.2012.04.002.

Cahyono F, Manongga SP, Picauly I. 2016. Faktor penentu stunting anak balita pada berbagai zona ekosistem di Kabupaten Kupang. J Gizi Pangan 11(1): 9-18.

Candra A. 2013. Hubungan underlying factors dengan kejadian stunting pada anak 1-2 th. J Nutr Health 1(1): 1-12.

Damayanti RA, Muniroh L, Farapti. 2016. Perbedaan tingkat kecukupan zat gizi dan riwayat pemberian asi eksklusif pada balita stunting dan non stunting. Media Gizi Indonesia 11(1): 61-69.

[EFSA] 2010. Scientific Opinion on Lead in Food. EFSA J 8(4): 1–151. DOI: 10.2903/j.efsa.2010.1570.

Febriwani FW, Elliyanti A, Reza M. 2019. Analisis kadar timbal (Pb) air minum isi ulang pada depot air minum (DAM) di Kecamatan Padang Timur Kota Padang tahun 2017. J Kesehatan Andalas 8(3): 668-676. DOI: 10.25077/jka.v8.i3.p668-676.2019.

Gleason KM, Valeri L, Shankar AH, Hasan MOSI, Quamruzzaman Q, Rodrigues EG, Christiani DC, Wright RO, Bellinger DC, Mazumdar M. 2016. Stunting is associated with blood lead concentration among Bangladeshi children aged 2-3 years. Environ Health 15(1): 1–9. DOI: 10.1186/s12940-016-0190-4.

Grandjean AC. 2004. Water Requirements, Impinging Factors and Recommended Intakes. The Center for Human Nutrition University of Nebraska: 25–40.

Guelinckx I, Iglesia I, Bottin J.H, De Miguel‐Etayo P, González‐Gil E.M, Salas‐Salvadó J, Kavouras SA, Gandy J, Martinez H, Bardosono S, Abdollahi M, Nasseri E, Jarosz A, Ma G, Carmuega E, ·Thiébaut I, Moreno LA. 2015. Intake of water and beverages of children and adolescents in 13 countries. Eur J Nutr 54(Suppl 2): 69-79. DOI: 10.1007/s00394-015-0955-5.

Harjatmo TP, Herlianty MP, Hartono AS. 2018. Stunting on toddler years on family of beneficiary family hope program in Wonogiri district, Central Java. Int J Community Med Public Heal 5(7): 2735. DOI: 10.18203/2394-6040.ijcmph20182607.

Herman H. 2018. Analisis Kadar timbal (Pb) pada air yang melalui saluran pipa penyalur perusahaan daerah air minum (PDAM) Makassar. J Media Analisis Kesehatan 8(2): 91-99. DOI: 10.32382/mak.v8i2.848.

Hua M, Zhang S, Pan B, Zhang W, Lv L, Zhang Q. 2012. Heavy metal removal from water/wastewater by nanosized metal oxides: A Review. J Hazard Mater 211–212(2012): 317-331. DOI: 10.1016/j.jhazmat.2011.10.016.

[Indonesian FDA] Indonesian Food and Drug Authority. 2018. Peraturan Badan Pengawas Obat dan Makanans Nomor 22 Tahun 2018 Tentang Pedoman Pemberian Sertifikasi Produksi Pangan Industri Rumah Tangga. Jakarta, BPOM RI.

Juric AK, Batal M, David W, Sharp D, Schwartz H, Ing A, Fediuk K, Black A, Tikhonov C, Chan HM, Chan

L. 2018. Risk assessment of dietary lead expo-sure among first nations people living on-reserve in Ontario, Canada using a total diet study and a proba-bilistic approach. J Hazard Mater 344(2018): 55-63. DOI: 10.1016/j.jhazmat.2017.09. 035.

Kabuhung A, Sembel D, Rumengan IF. 2013. Kadar logam berat (Pb, Cd, Hg dan As) pada sumber dan air minum isi ulang (AMIU) di Kota Manado. J Ilmu Teknol Pangan 1(1): 30–40.

Kurnianingtyas S, Sartika R, Ningsih W. 2021. Under-weight in Child Aged 24-59 Months in North Sumatera: the 2014 Indonesia Family Life Survey Data. Indonesian J Public Health Nutr 1(2): 40-49.

[MoH RI] Ministry of Health Republic of Indonesia. 2013. Riset Kesehatan Dasar 2013. Jakarta: Badan Litbangkes.

[MoH RI] Ministry of Health Republic of Indonesia. 2014. Buku Studi Diet Total: Survey Konsumsi Makanan Individu Indonesia 2014. Jakarta: Badan Litbangkes.

[MoH RI] Ministry of Health Republic of Indonesia. 2015. Buku Studi Diet Total ACKM Analisis Cema-ran Kimia Makanan. Jakarta: Badan Litbangkes.

[MoH RI] Ministry of Health Republic of Indonesia. 2020. Standar Antropometri Anak. Jakarta: Badan Litbangkes.

[NSA RI] National Standardization Agency of Indonesia. 2009. SNI 6989.46:2009 Air dan air limbah - Bagian 46: Cara uji timbal (Pb) secara Spektrofotometri Serapan Atom (SSA) - tungku karbon. Jakarta: Badan Standardisasi Nasional.

Pacheco CDR, Picauly I, Sinaga M. 2017. Health, food consumption, social economy, and stunting inci-dency in Timor Leste. J Kesehatan Masyarakat 13(2): 261-269. DOI: 10.15294/kemas.v13i2.112 48.

Picauly I, Toy SM. 2013. Analisis Determinan dan pengaruh stunting terhadap prestasi belajar anak sekolah di Kupang dan Sumba Timur, NTT. J Gizi Pangan 8(1): 55-62. DOI: 10.25182/jgp.2013.8.1. 55-62.

Reurings M, Vossenaar M, Doak CM, Solomons NW. 2013. Stunting rates in infants and toddlers born in metropolitan Quetzaltenango, Guatemala. Nutrition 29(4): 655-660. DOI: 10.1016/j.nut.2012.12.012.

Schober P, Boer C, Schwarte LA. 2018. Correlation coefficients: Appropriate use and interpretation. Anesthesia & Analgesia 126(5): 1763-1768. DOI: 10.1213/ANE.0000000000002864.

Sui Z, Zheng M, Zhang M, Rangan A. 2016. Water and beverage consumption: Analysis of the Australian 2011–2012 national nutrition and physical activity survey. Nutrients 8(11): 678. DOI: 10.3390/nu8110 678.

Sukoasih A, Widiyanto T, Suparmin. 2017. Hubungan antara suhu, pH dan berbagai variasi jarak dengan kadar timbal (Pb) pada badan air sungai rompang dan air sumur gali industri batik Sokaraja Tengah Tahun 2016. Buletin Keslingmas 36(4): 360–368. DOI: 10.31983/keslingmas.v36i4.3115.

Susetyowati, Palupi IR, Rahmanti AR. 2017. Associa-tion of household food security with toddler stunting in the Sleman Regency Indonesia. Int J Community Med Public Health 4(5): 1424. DOI: 10.18203/ 2394-6040.ijcmph20171750.

Wang M, Liang B, Zhang W, Chen K, Zhang Y, Zhou H, Cheng Y, Liu H, Zhong X, Li Y, Liu Y. 2019. Dietary lead exposure and associated health risks in Guangzhou, China. Int J Environ Res Public Health 16(8): 1417. DOI: 10.3390/ijerph16081417.

Weya A, Rantetampang AL, Tingginehe R, Mallongi A. 2018. Factors affecting nutrient status of toddler years at Puncak Jaya District Sub Province Papuan. Int J Sci Healthcore Res 3(4): 70–80.

[WHO] 2009. Principles and Methods for the Risk Assessment of Chemicals in Food Chapter 6 : Dietary Exposure Assessment of Chemicals in Food.

Zhang N, Morin C, Guelinckx I, Moreno L.A, Kavouras S.A, Gandy J, Martinez H, Salas‐Salvadó J, Ma G. 2018. Fluid intake in urban China: results of the 2016 Liq.In7 national crosssectional surveys. Eur J Nutr 57(Suppl 3): 77-88. DOI: 10.1007/s00394-018-1755-5.

Zilda O, Sudiarti T. 2013. Faktor risiko stunting pada balita (24-59 bulan) di Sumatera. J Gizi Pangan 8(3): 175-180. DOI: 10.25182/jgp.2013.8.3.177-180.

JMP-03-22-05-Naskah diterima untuk ditelaah pada 18 Januari 2022. Revisi makalah disetujui untuk dipublikasi pada 10 April 2022. Versi Online: http://journal.ipb.ac.id/ index.php/jmpi