Conference Paper

Well-Water Consumption of High Cadmium and the Resulting Urinary Cadmium Levels in a Community near a Dumping Site

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Abstract

Cadmium (Cd) is a nephrotoxic metal that can accumulate in the kidneys for a long time, damaging the kidneys' tubules and leading to renal failure. This study aimed to determine the relationship between the consumption of well water exposed to Cd and urinary Cd.

The cross-sectional study was performed in the community near the Namo Bintang dumpsite. The sample population of 99 people was selected by stratified random sampling based on the distance of the individual's home from the landfill. Cd was measured via GFAAS, and the data was analyzed by correlation and regression (well-water Cd, age, volume of water intake, duration of Cd intake), independent sample t-test (gender, occupational, smoking habit, BMI), and multiple linear regression.

The study's results showed that 65 respondents (65.7%) had been exposed to Cd higher than the normal level (0.005mg/l) and that 99 urine samples (100%) had high Cd levels above the normal level (5 μg/g creatinine). There was no significant correlation between the well's Cd level and urinary Cd. The variables of gender, BMI, and the duration of Cd intake had significant correlations with urinary Cd (p-values of 0.045, 0.025, and 0.041, respectively). Therefore, the residents were instructed to not use well water as their primary source of drinking water.

Keywords: cadmium; urinary Cd; dumpsite area; nephrotoxic metal

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1. INTRODUCTION

Landfills are a known source of cadmium (Cd), which can come from plastic waste, batteries, electronic waste, and industrial waste (Prudent et al. 1996) [7]. Open dumping methods of waste management may exacerbate the problem, resulting in environmental pollution around the landfill due to leachate. The Cd derived from leachate water will seep into the ground and possibly contaminate the well water for residents living near the landfill. Leachate can also degrade the quality of groundwater [11].

If consumed by residents, Cd-contaminated well water will irritate the stomach and lead to nausea, vomiting, diarrhea, and even death. Cd consumption in low concentrations over a long period of time will accumulate in the kidneys, and high levels will cause kidney damage [3].

Cd contamination can also cause cardiovascular disorders [4, 9, 15, 21]. The most famous case due to being orally exposed to Cadmium is itai-itai disease, which was caused by Cd-contaminated food and water in Toyama Society, Japan [23]. Cd concentration in the human body can be measured through the blood, urine, breast milk, liver, kidneys, hair, and nails [23]. Various studies have shown a significant relationship between Cd exposure and its concentration in urine [2].

The Namo Bintang village in Kabupaten Deli Serdang has landfill that used the open dumping method. Although the Namo Bintang landfill has closed, the existing garbage was left without being enclosed or moved to another location. Thus, there was a significant possibility of the landfill leachate contaminating the surrounding environment, as leachate formation may continue for 20–30 years after the landfill ceases operation [16, 20].

The surrounding Namo Bintang community resides within a 100-meter radius of the landfill. Meanwhile, according to the Indonesian National Standard (SNI) No. 03-3241-1994 on Procedures for Landfill Site Selection, the nearest settlement should be at least 500 meters from a landfill. The Namo Bintang landfill's surrounding community is still using groundwater or well water for drinking, which can potentially include the contaminated leachate produced from the landfill's biodegradable waste [5].

The village is located within a radius of 200 meters to the west of the Namo Bintang landfill. In this village, the Cd concentration from all 30 wells exceeded the water-quality standards, with the lowest concentration being 0.213 mg/l (42.6-times higher than the quality standard) and the highest concentration being 0.531 mg/l (106.2-times higher than the quality standard; [13]).

This study aimed to determine the relationship between the consumption of well water containing Cd with the Cd concentration in the urine of the residents who lived near the dumpsite.

2. METHODS

This study was an observational quantitative study that used a cross-sectional design to examine the community around the Namo Bintang dumpsite, Deli Serdang District, North Sumatera Province. The study's population consisted of 99 men and women who were older than 18, who had lived at least seven years in the study site, and who used non-chemically treated well water as a main source for drinking water and cooking. The subjects were selected by stratified random sampling based on the distance of their homes from the landfill. Informed consent was obtained from the respondents. This study received ethical approval from the Health Research Ethical Committee of Universitas Indonesia No. 230/UN2.F10/PPM.00.02.2016, Indonesia.

Water samples were collected from the wells around the dumpsite to measure Cd levels; the Cd level in water will not decrease in boiling water. The area selected was approximately < 1 km and > 1 km radius from the dumpsite. The samples were collected in 1-liter, sterile polythene bottles.

A total of 99 urine samples were collected in the morning as spot samples from adults in the Namo Bintang area and then transported to the environmental laboratory for analysis. These urine samples were collected directly in disposable polypropylene containers that had been deionized (free from heavy metals) and washed with 5% nitric acid. The collected urine samples were analyzed with Polarized Zeeman Graphite Furnace Atomic Absorption Spectrophotometer Z-5700 (GFAAS), using the direct method to measure the Cd concentration in the urine samples under the Standard Method.

3. Results

In this study, the urinary Cd data were not normally distributed; therefore, the Cd levels in urine were transformed into logarithms, resulting in normally distributed data. Furthermore, the ACGIH's urinary Cd quality standard was transformed into logarithms; thus, the biological exposure indices (BEI) of the Cd in urine were initially 5 μg/g creatinine to 0.7 μg/g creatinine [6].

Table 1 shows the respondents' urinary Cd levels ranged between 0.78 to 2.31 μg/g creatinine, the mean was 1.423 with a standard deviation of ± 0.312μg/g creatinine. The mean Cd of the well water was 0.007 mg/l, which means the respondents had been exposed to Cd higher than the normal level of 0.005 mg/l (SNI 7387-2009).

Table 1: Descriptive Statistics of Urinary Cd Level and Cd of Well Water

Variable	Mean	Median	SD	Min-Max	95% CI
Urinary Cd level (μg/g creatinine)	1.423	1.350	0.312	0.780-2.310	1.361-1.485
Cd of well water (mg/l)	0.007	0.008	0.005	0.002-0.020	0.006-0.008

Table 2: Correlation and Regression Analysis between Cd of Well Water, Age, Volume of Water Intake, Duration of Cd Intake from Water, and Urinary Cd Level

Variable	Mean ± SD	R	R-square	Regression Equation	P-value
Cd of well water (mg/l)	0.007 ± 0.005	-0.081	0.007	$Y=1.463-5.509X_1$	0.423
Age (years)	42.32 ± 13.071	-0.132	0.017	$Y=1.556-0.003 X_2$	0.194
Volume of water intake (l/day)	0.00002 ± 0.0001	-0.149	0.022	$Y=1.474-320.3 X_3$	0.142
Duration of Cd intake from water (years)	18.22 ± 12.67	-0.206	0.042	$Y=1.515-0.005 X_4$	0.041

Table 2 shows no significant association between the Cd of well water, age, and volume of water intake and the urinary Cd level (p-value > 0.05); however, the duration of Cd intake from water and the urinary Cd level had a significant association (p-value = 0.041).

4. Y = Urinary Cd; X_1 = Cd of well water; X_2 = age; X_3 = volume of water intake; X_4 = duration of Cd intake.

Figure 1 shows the correlation between the Cd of well water and the measured urinary Cd level.

Table 3 shows a significant association between gender, BMI (body mass index), and urinary Cd level (p-values of 0.045 and 0.025, respectively); however, occupational exposure to Cd, smoking habit, and urinary Cd level had no significant association (p-value > 0.05).

Table 4 is the final modeling of the multivariate analysis using a multiple linear regression to analyze the correlation between well-water Cd and urinary Cd levels, and it is controlled by the variables of age, gender, occupational exposure, smoking habits, the volume of water intake, duration of Cd intake from water, and BMI.

Based on the above model, any increase in well-water Cd levels of 1 mg/l can reduce urinary Cd levels at 15.189μg/g creatinine after controlling for the variables of age, gender, occupational exposure, smoking habit, volume of water intake, duration of Cd intake from water, and BMI. The regression equation Y (urinary Cd) = 1.342 − 15.189

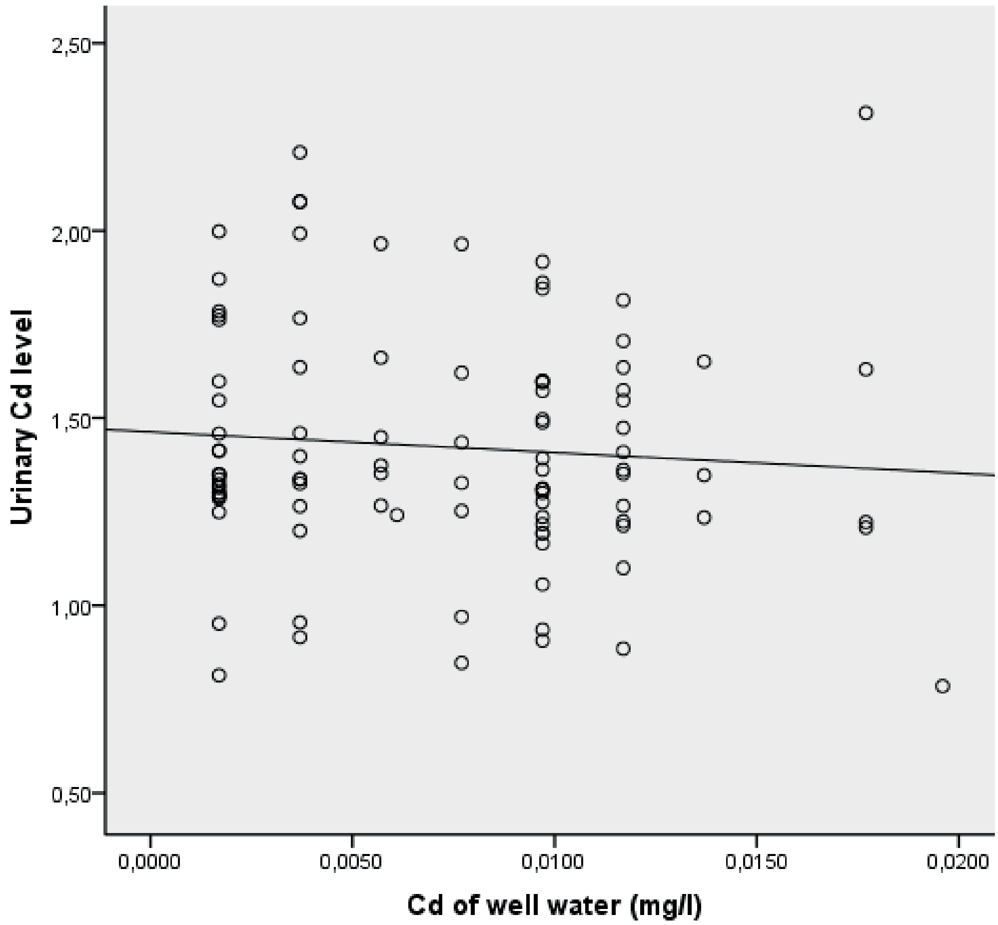

Figure 1: Correlation between Cd of well water and measured urinary Cd level.

(well-water Cd) – 0.003 (age) + 0.324 (gender) + 0.191 (occupational exposure) + 0.270 (smoking habit) + 326.366 (volume of water intake) – 0.003 (duration of Cd intake from water) – 0.084 (BMI).

5. Discussion

Urinary Cd is commonly interpreted in epidemiological studies to measure the Cd accumulated in the body, such as in the kidneys, and it is used as a marker of long-term exposure [12]. Based on the study's results, there was no significant relationship between well-water Cd levels and the Cd in urine. Consumption of drinking water obtained from polluted sources makes only a small contribution to the total dietary Cd intake. Contamination of water sources or Cd dissolution of the pipes or other plumbing fixtures could produce a more significant contribution. The available data indicate that in most cases, the water contributed more than 0.01 mg/day of Cd into the body,

Table 3: Independent Samples T-Test Analysis between Gender, Occupational Exposure to Cd, Smoking Habit, BMI, and Urinary Cd Level

Variable	N	Mean	SD	SE	P-value
Gender					
Males	26	1.318	0.285	0.056	0.045
Females	73	1.461	0.314	0.037	
Occupational exposure to Cd					
Not exposed	89	1.403	0.293	0.031	0.061
Exposed	10	1.598	0.422	0.134	
Smoking habit					
No	59	1.375	0.288	0.038	0.063
Yes	40	1.494	0.334	0.053	
BMI					
Obese	29	1.482	0.376	0.070	0.025
Not Obese	70	1.399	0.280	0.034	

*n = Subjects; SD = Standard deviation; SE = Standard error.

Table 4: The Final Model of Multivariate Analysis with a Multiple Linear Regression for Well-Water Cd and Urinary Cd Level

Variable	$Coef_{adjusted}$	P-value	95% CI	
Well-water Cd	-15.189	0.118	-34.312	3.934
Age	-0.003	0.262	-0.007	0.002
Gender	0.324	0.001	0.157	0.490
Occupational exposure to Cd	0.191	0.063	-0.010	0.391
Smoking habit	0.270	0.001	0.119	0.422
Volume of water intake (l/day)	326.366	0.382	-411.660	1064.390
Duration of Cd intake from water (years)	-0.003	0.383	-0.010	0.004
BMI	-0084	0.198	-0.212	0.045
Constant	1.342			

assuming the maximum Cd concentration is 0.005 mg/L and the daily consumption of 1.5 L per adult [23].

The study's results showed no significant relationship between age and urinary Cd. These results are similar to the findings of Sirivarasai et al. (2002), who stated there was no significant relation between age and Cd levels in respondents' urine, with a p-value > 0.05. However, these results differ from other studies that stated Cd in the urine will increase according to age [18].

Gender was among the risk factors tested in this study, and the results are similar to the findings of Adnan et al. (2012), who showed that the Cd levels in women's urine is higher than in men's urine. These studies proved that low iron levels can enhance the gastrointestinal absorption of Cd through food [1]. This study's results are different from previous studies conducted on workers in industries that are exposed to Cd, which showed that Cd causes renal tubular dysfunction dependent upon the dose and the occurrence of tubular proteinuria after reaching a critical threshold value [17]. In workers exposed to Cd, the concentration of urinary Cd was more than 300 µg/g creatinine, indicating possible kidney disease [3]. In another study in Thailand, there was no significant Cd levels in urine among people who were not exposed to Cd at work and those who were. This study's results showed a decreased concentration of Cd in blood and urine in the general population compared with people who have work exposure to Cd [14, 19].

In this study, the Cd content in the urine of smokers is higher than in the urine of respondents who were non-smokers. Based on statistical tests, no significant relation was found between Cd in urine and smoking habits. These results conflict with previous studies, which had shown Cd levels in smokers' blood and urine were higher than in non-smokers blood (0.98 vs 0.86 µg/l; $p < 0.05$) and urine (0.95 µg/g creatinine vs 0.74 µg/g creatinine; $p < 0.05$; Sirivasarai et al. 2002).

In this study, there was a significant relationship between nutritional status (BMI) and Cd in urine. These results are similar to studies conducted by Akesson et al. (2008); however, another study found no difference in the significant proportion for high Cd levels in urine based on obesity from 300 adult residents in Tanjung Karang, Malaysia [1].

The statistical analysis found a significant relationship between exposure duration and urinary Cd levels. Prolonged Cd exposure can cause bone disease, which was first reported on the river Jinzu in Japan, where approximately 150 cases of itai-itai disease have been diagnosed. The Cd exposure came from contaminated river water used for irrigating rice fields. Most itai-itai patients are women in their 40s who have lived in the endemic areas for more than 30 years. The Cd concentrations found in their bones was several times higher than in people who were not exposed [10].

In this study, there was no significant relationship between the water intake amount and Cd in urine. Based on another study with a cross-sectional design that included 120 children between 6-11 years old who had mothers over the age of 45, the use of well water as the main source of drinking water had a significant association with higher levels of Cd in the smoking mothers' urine [8].

6. Conclusions

This study found no significant correlations between Cd levels from wells and urinary Cd; however, the wells' Cd levels revealed that 65.7% had been exposed to Cd higher than normal levels and that all urine samples had Cd levels above normal levels. Further research is suggested to measure biomarkers of other effects, such as the measurement of metallothionein urine as an indicator of kidney damage. Therefore, residents are recommended to not use well water as their main resource for drinking water, and this study's results are expected to be utilized by the Deli Serdang Regency's government as a basis for water and sanitation planning in the study area.

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References

[1] Adnan, Jawdat A., Shah S. Azhar, Jaafar M. Hasni, and Jadoo S. Ahmad. 2012. "Urinary cadmium concentration and its risk factors among adults in Tanjung Karang, Selangor." American-Eurasian Journal of Toxicological Sciences 4 (2): 80-88.

[2] Agency for Toxic Substances and Disease Registry - ATSDR. 2008. Toxicological Profile for Cadmium. Atlanta, GA: US Department of Human and Health Services. Accessed June 21, 2017. http://www.atsdr.cdc.gov/toxprofiles/TP.asp?id=48&tid=15.

[3] Agency for Toxic Substances and Disease Registry - ATSDR. 2012. Toxicological Profile for Cadmium. Atlanta, GA: US Department of Human and Health Services. Accessed June 21, 2017. https://www.atsdr.cdc.gov/toxprofiles/tp5.pdf.

[4] Akesson, Agneta, and Marika Berglund. 2008. “Cadmium exposure in pregnancy and lactation in relation to iron status.” American Journal of Public Health 92 (2): 284-287.

[5] Ashar, Taufik, Wirsal Hasan, Hamonangan Nainggolan, and Erman Munir. 2016. “Correlation of Cadmium Intake from Water and Biomarkers in Resident Living Around Namobintang Dumpsite.” Indonesian Journal of Chemistry 16 (1).

[6] Association Conference of Governmental Industrial Hygienists - ACGIH. 2007. Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs). Cincinnati, OH: American Conference of Governmental Industrial Hygienist. Accessed June 21, 2017. https://www.osha.gov/dts/osta/otm/otm_ii/pdfs/otmii_chpt2_appb.pdf.

[7] Aucott, Michael. 2006. The Fate of Heavy Metals in Landfills: A Review Industrial Ecology, Pollution Prevention and the NY-NJ Harbor. New York: New York Academy of Sciences.

[8] Berglund, Marika, Agneta Akesson, Barbro Nermell, and Marie Vahter. 2015. “Intestinal absorption of dietary cadmium in women is dependent on body iron stores and fiber intake.” Environ Health Perspect 102: 1058-66.

[9] Everret, Charles, and Ivar L. Frithsen. 2008. “Association of urinary cadmium and myocardial infarction.” Environ Res: 284-286.

[10] Gonick, H. C. 2008. “Nephrotoxicity of cadmium and lead.” Indian J Med Res, 128: 335-352.

[11] Iqbal, Mohammad A., and S G. Gupta. 2009. “Studies on Heavy Metal Ion Pollution of Ground Water Sources as an Effect of Municipal Solid Waste Dumping.” African Journal of Basic and Applied Sciences 1 (5-6): 117-122.

[12] Jarup, Lars, and Agneta Akesson. 2009. “Current status of cadmium as an environmental health problem.” Toxicol Appl Pharmacol 238 (3):201–208.

[13] Nainggolan, Adolpino. 2011. Analisa Kandungan Kadmium Sumur Gali Masyarakat di Sekitar TPA Namobintang Kecamatan Pancurbatu Kabupaten Deli Serdang Tahun 2011. Undergraduate thesis, Universitas Sumatera Utara.

[14] Pavittranon, Sumol, and Punthip Teeyapant. 1995. “A report on blood lead level in Thai population 1987-1992.” Bull Dept Med Serv 37: 11-7

[15] Peters, Junenette L., Todd S. Perlstein, Melissa J. Perry, Eeleen McNeely, and Jennifer Weuve. 2010. “Cadmium Exposure in Association with History of Stroke and Heart Failure.” Environ Res 110 (2): 199-206.

[16] Qasim, Syed. 1994. Sanitary Landfill Leachate Generation, Control & Treatment, Technomic Publishing Company. Texas: CRC Press.

[17] Roels, Harry, and Perrine Hoet. 1999. "Usefulness of Biomarkers of Exposure to Inorganic Mercury, Lead, or Cadmium in Controlling Occupation and Environmental Risks of Nephrotoxicy." Renal Failure, 21: 3-4.

[18] Sirivarasai, Jintana, S. Kaojaren, W. Wananukul, and P. Srisomerang. 2002. Non-Occupational Determinant of Cadmium and Lead in Blood and Urine Among a General Population in Thailand., vol.33. Accessed June 21, 2017. http://www.tm.mahidol.ac.th/seameo/2002_33_1/32-2713.pdf.

[19] Taveepong, S., V. Sripiron, H. Sriburi, and B. Panjaburi. 1999. "Blood Lead Levels in Normal People and Workers in Factories of the Northern Industrial Estate." Bull Chiang Mai Assoc MedSci, 32: 3-9.

[20] Tchobanoglous, George, and Hilary Theisen. 1993. Integrated Solid Waste Management. The University of Michigan: Mc Graw-Hill International Edition.

[21] Tellez-Plaza, Maria, Ana Navas-Acien, Kathleen Caldwell, Andy Menke, Paul Muntner, and Eliseo Guallar. 2012. Reduction in Cadmium Exposure in the United States Population, 1988-2008, The Contribution of Declining Smoking Rates. Environmental Health Perspectives 120.

[22] World Health Organization – WHO (World Health Organization). 2004. Cadmium in Drinking Water, Background Document for Development of WHO Guidelines for Drinking Water Quality. Geneva: World Health Organization.

[23] World Health Organization – WHO (World Health Organization). 2010. Exposure to Cadmium a Major Public Health Concern. Geneva: World Health Organization. Accessed June 21, 2017. http://www.who.int/ipcs/features/cadmium.pdf.