

The Human Health Risk of Cadmium (Cd), Mercury (Hg), and Lead (Pb) Exposure in The Upper Citarum River Basin, West Java, Indonesia

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Abstract— The Citarum River is the longest river in West Java stretching from Bandung City to the Jakarta bay. This river has been utilized as a vital object to provide power generation, irrigation, drinking water, and household utilities. The existence of heavy metals such as mercury (hg), cadmium (Cd), & Lead (Pb) in the river has become a serious concern. This research was aimed to analyze human health risk exposed by heavy metals from the consumption of the water, fish, and vegetables around the upper Citarum River. A number of 100 human samples were included in this study. River water, well water, fish, & vegetables were collected around The Citarum River to analyze heavy metals content (Hg, Cd, and Pb). In this research, the concentration of Cd in all samples were below the standard limit. The concentration of Hg in fish & vegetables samples ranged from 0.17 – 0.78 mg/kg and <0.02 – 0.042 mg/kg, respectively. Meanwhile, Hg concentration was below the limit of detection for river and well water. Pb concentration in river, well water and vegetables were below 0.005 mg/l & below 0.1 mg/kg, respectively. Pb concentration in fish samples ranged from < 0.1 – 0.28 mg/kg. In this result, we found that fish sample D had the highest concentration for all heavy metals than other samples. It was estimated that fish samples around the upper Citarum River were not safe for consumption based on Hg tolerable daily intake with risk question (RQ) value was over than 1. However, it was still tolerable for Cd and Pb.

Keywords— health risk, heavy metals, mercury, lead, cadmium, citarum river, food

1. Introduction

The Citarum River has been utilized by the residents to provide waterpower generation to produce 2000 MW covering Java, Madura, and Bali. This river is also used to provide drinking water sources (6%), irrigation (86.7%), urban water support (0.37%), and household industry (2%) [1]. The Citarum River is the longest in West Java stretches from Bandung City to Jakarta Bay for 269 km [2]. However, the increase of industrial activities has turned this river into the most polluted river in the world [3]. The pollution was emitted from domestic and industrial waste. The Indonesian Ministry of Environment Data and Information Center showed that the water quality index in West Java decreased from 2013 to 2017 [1]. Currently, industrial activities have increased rapidly in Indonesia, including the textile industry. According to the Ministry of Industry of Indonesia in 2016, the largest number of industries in Indonesia was located in West Java, 54% of industrial areas were located in West Java. It impacted the decline in river water quality, especially the Citarum River [4].

The waste in the Citarum River consists of human feces around 35.5 tons/day, animal feces around 56 tons/day, industrial waste around 340,000 tons/day, plastic waste of 20.462 tons/day, and various unspecified amounts of medical waste [5]. In addition, the Deputy for Human Resources, Science and Technology, and Maritime quoted from CNN Indonesia said that 1,629 industries were operating along the Citarum river, 185 of them were operated without wastewater management system. The waste generated by the industry was considered as the main pollutant in the Citarum River basin [6]. There were about 2.700 industrial sites with large and middle scale located around the Citarum River basin. These industries contributed 20% of total production in Indonesia. Around 60% of total industries in the Citarum River Basin were national textile industries with an estimation of 2800 tons of waste per day [7]. The wastewater was

discharged directly or through an underground pipe to the river flow illegally. Miryanti and Witono[8] reported that textile wastewater from coloring and printing plants contained toxic heavy metals to human health such as mercury (Hg), Cadmium (Cd), and Lead (Pb).

Research conducted by Arief et al., [9] investigated the concentration of Cd and Pb in Citarum River water samples showed elevated concentration. Cd concentration ranged from 0.007 – 0.01 mg/l which exceeded the national standard for river water (0.003 mg/l). Pb concentration ranged from 0.05 – 0.08 mg/l in water samples which also exceeded the national standard for river water (0.008 mg/l). Beside that, Sudarningsih and Bijaksana[10] showed Hg content in Citarum River water at 0.07 mg/l. Heavy metals such as Pb, Hg, and Cd have high toxicity to human health. It can accumulate in the food chain such as fish and vegetables, then enter the human body through food consumption [11].

Exposure to Hg can cause neurological damage, cardiovascular, hematological, respiratory problems, and kidney damage. In the central nervous system, mercury can cause coordination disorder, causing depression, tremors in body parts, prolonged fatigue and causing abnormal movements [12]. Cd also can cause cell damage by inhibiting apoptotic activities, induction of cell death to promote kidney tissue damage [13]. Cd is also reported to interact with bone cells and cause osteoporosis. In addition, Cd metal poisoning can cause disturbances in the reproductive system such as impaired spermatogenesis, sperm quality, and ovarian bleeding [14]. At an advanced level, Cd is also referred to as a carcinogenic metal that triggers breast cancer and pancreatic cancer [15]. Exposure to lead (Pb) has been reported to cause reproductive problems such as reduced sperm quantity, causing sperm mortality and damage, in cases of severe poisoning can cause miscarriage and low birth weight [16]. In addition, Pb in the blood can cause a decrease in hemoglobin levels even though in low concentration (< 40 g/dL) [17].

Taufik et al., [18] revealed that fish tissue in the Upper Citarum River generally contains lead and cadmium exceeded the threshold of national quality standards. According to Nasrun et al. [19], absorption of heavy metals such as lead in fish consumed by humans can affect human health because of the risk of poisoning. Anggraini et al. [20] found that 70% of residents had the potential risk of disease due to heavy metals content in tilapia with an exposure period of 30 years. The symptoms such as headache, nausea, vomiting, and diarrhea. The health risk increased due to the increase of fish intake from heavy metals-contaminated fish [21].

The existence of heavy metals in the river water will also be absorbed and accumulated by plants such as vegetables. Vegetables easily respond to the substances contained in their growing media and absorb them throughout the plant. Furthermore, the metal will be accumulated in the plant in a certain level. As a result, humans who consume contaminated vegetables will be at risk of experiencing health problems [22]. It is necessary to identify toxic heavy metals in plants to evaluate the level of contamination in food. However, data on the analysis of the health risks of heavy metals in vegetables in the upper Citarum River has never been carried out [23].

Many people around the Citarum River, Majalaya Subdistrict, complained of various types of diseases such as dry and cracked skin, and nervous system disorders [24]. It was reported that residents in Majalaya experienced skin diseases, digestion problem, respiratory disorders with a number of visits by more than 7,000 people related to similar health problems [25].

Health risks will continue to increase with the existence of the food chain cycle [26]. The consumption of heavy metals-contaminated food such as fish and vegetables or contaminated water will pose to increase of human health risk. The accumulation of the toxic heavy metals in the human body will can cause several health problems including organ damage [27,28,29]. Therefore, it is necessary to identify and evaluate the content of heavy metals in water, fish, and vegetables to estimate human health risk in the upper Citarum River area.

2. Materials and Method

This research was conducted in the upper Citarum river area, Majasetra Village, Bandung regency, West Java. Research respondents were calculated using the slovin formula from a total population of 50,157 people. A number of 100 resident samples were included. The community sampling method is done randomly (random sampling) by directly visiting the respondents who are willing to join as research samples. Three kinds of environmental samples were collected (water, fish and vegetables). The river water and well water samples were collected at 3 different points and well at 3 different locations located close to the Citarum river. The water samples were then stored into sample bottles for further transport and analysis in the laboratory. 2 types of most consumed fish were collected (tilapia and carp) from 2 different locations: fish market and pond. Vegetable samples were selected from 2 types of vegetables that are often consumed by the local community (spinach and kale). Each type of vegetable was sampled in 2 different locations from market and vegetables store. All samples were then stored into a cool box to maintained the quality for further transport and analysis in the laboratory.

Demographic and health data of the respondents were collected using a standard questionnaire including age, gender, weight, height and occupation, the health condition of the respondents in the last 1 year, illnesses experienced in the last 1 year, food frequency, and consumption data. All respondents were asked for their willingness to join the research by signing the informed consent before interview. Research questionnaires were distributed to the respondents who were used as respondents or research samples to collect data/information about the characteristics of respondents the last year and the place of treatment when sick, the respondent's fish consumption pattern includes the type of fish consumed, the source of fish and the amount of fish consumption in 1 day, and the respondent's vegetable consumption pattern includes the type of vegetable consumed, the source of the vegetable, the amount of vegetable consumption in 1 week and the method consume vegetables.

The concentration of heavy metals (Hg, Cd, and Pb) in all samples were deterimed by the Atomic Absorption Spectrophotometry technique using Shimadzu AA-7000 and MVU Shimadzu machine. The results are interpreted and compared to the national threshold limit for heavy metal content in water, fish and vegetables. The analysis was carried out in six times for each sample to ensure results validity.

Health risk analysis was calculated by the Environmental Health Risk Analysis technique using the following formula:

$$I_{nk} = \frac{C \times R \times f_E \times D_t}{W_b \times t_{avg}}$$

I = heavy metals intake from food (mg/kg body weight/day)

C = heavy metals concentration in the samples

R = consumption rate (g/day)

fE = consumption frequency in a year (day/year)

Dt = exposure duration (year)

Wb = body weight

Tavg = the averaging time of non-carcinogenic exposure (Dt x 365 days)

Intake was then compared to daily tolerable intake or Reference Dose (RfD) of Hg (0,00057 mg/kg/day), Cd (0,0005 mg/kg/day), and Pb (0,000493 mg/kg/day) to obtain risk question (RQ). RQ value over than 1 (RQ>1) is considered as not safe for consumption.

3. Results

The demographic distribution of the respondents in this study are presented in Table 1. The characteristics of respondents based on age were 48-61 years old (39%) with almost all of the respondents were female (92%). Body weight of the respondents ranged from 42-97 kg.

Table 1. The distribution of demographical characteristics based on age, gender, weight, height and occupation

Variables	n	Percentage
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Variables	n	Percentage
<i>Age</i>		
20 – 33 Years	15	15,00%
34 – 47 Years	34	34,00%
48 – 61 Years	39	39,00%
62 – 76 Years	12	12,00%
<i>Genre</i>		
Male	8	8,00%
Female	92	92,00%
<i>Body Weight</i>		
42 – 55 Kg	27	27,00%
56 – 69 Kg	43	43,00%
70 – 83 Kg	24	24,00%
84 – 97 Kg	6	6,00%
<i>Height</i>		
135 – 144 Cm	3	3,00%
145 – 154 Cm	22	22,00%
155 – 164 Cm	58	58,00%
165 – 174 Cm	17	17,00%
<i>Occupation</i>		
Household wife	81	81,00%
Entrepreneur	8	8,00%
Labor	9	9,00%
Student	2	2,00%

Table 2 shows the consumption pattern of vegetables consumed by the respondents. The types of vegetables that are often consumed are spinach and kale (50%), the most vegetable sources buy in the stalls are 57 people (57%), the amount of vegetable consumption in 1 day is at most 5 times, namely 38 people (38%), all respondents washed vegetables before cooking (100%). Based on Table 3, it showed that goldfish was the most consumed fish among the respondents (52%), 56% of the respondent obtained the fish from the fish store. Almost all of respondent consumed fish 2 times per day (64%). Some of the respondents consume fish 4-5 times a day without rice.

Table 2. Vegetable types, sources of vegetables, and amount of vegetable consumption in 1 day.

Variables	n	Percentage
<i>Vegetables</i>		
Spinach	50	50,00%
Kale	50	50,00%
<i>Vegetable source</i>		
Membeli di Pasar	43	43,00%
Membeli di Warung	57	57,00%
<i>Amount of consumed per day</i>		
1 Time	1	1,00%
2 Times	6	6,00%
3 Times	10	10,00%
4 Times	24	24,00%
5 Times	38	38,00%
6 Times	21	21,00%

Table 3. Fish types, source of fish, and amount of fish consumption in 1 day

Variables	n	Percentage
<i>Fish Type</i>		
Nila	48	48,00%
Mas	52	52,00%

Variables	n	Percentage
<i>Fish Source</i>		
Membeli di Pasar	44	44,00%
Membeli di Warung	56	56,00%
<i>Amount of fish consumed per day</i>		
1 Time	–	–
2 Times	64	64,00%
3 Times	28	28,00%
4 Times	6	6,00%
5 Times	2	2,00%

The evaluation of heavy metal concentrations in the Citarum river was carried out by collecting river water samples at 3 different points/locations, then put them in a sample bottle and coded with Sample A (bottle 1), Sample B (bottle 2) and Sample C (bottle 3). The results showed that lead (Pb) and cadmium (Cd) content in the three Citarum river water samples were below the maximum threshold at 0.008 mg/l and 0.003 mg/l, respectively. The concentration of mercury content (Hg) were below the maximum threshold of 0.001 mg/l as well (Table 4).

Table 4. The concentration of heavy metals in river and well water

No	Metals	unit	National Standards	Sample A	Sample B	Sample C
<i>River Water</i>						
1	Lead (Pb)	mg/l	0,008	< 0,005	< 0,005	< 0,005
2	Cadmium (Cd)	mg/l	0,003	< 0,002	< 0,002	< 0,002
3	Mercury (Hg)	mg/l	0,001	< 0,0002	< 0,0002	< 0,0002
<i>Well water</i>						
1	Lead (Pb)	mg/l	0,008	< 0,005	< 0,005	< 0,005
2	Cadmium (Cd)	mg/l	0,003	< 0,002	< 0,002	< 0,002
3	Mercury (Hg)	mg/l	0,001	< 0,0002	< 0,0002	< 0,0002

Determination of heavy metals in the well water were also carried out at 3 different points/locations, then stored it in a sample bottle and coded it with Sample A (bottle 1), Sample B (bottle 2) and Sample C (bottle 3). The results showed that Pb, Cd, and Hg concentration in well water samples were still below the national threshold 0.008 mg/l, 0.003 mg/l, and 0.001 mg/l, respectively (Table 4).

The concentration of heavy metals in fish were carried out on tilapia and carp from 2 locations (fish market and pond). The samples were stored into a cool box and coded it with Sample A (market tilapia), Sample B (market carp), Sample C (market carp; pond tilapia) and Sample D (pond carp). The concentration of Pb in sample A, B, and C were below the national standard, but it exceeded the national standard for sample D 0.28 mg/kg. The cadmium (Cd) concentration in all fish samples were below the national threshold. The mercury (Hg) concentration was still below the national standard for sample A, B, and C. However, Hg concentration in sample D (pond carp) exceeded the national standard at 0.78 mg/kg (Table 5).

Table 5. The concentration of heavy metals in fish and vegetables.

No	Metals	Unit	National Standards	Sampel A	Sampel B	Sampel C	Sampel D
<i>Fish</i>							
1	Lead (Pb)	mg/kg	0,20	< 0,10	0,18	0,18	0,28
2	Cadmium (Cd)	mg/kg	0,10	< 0,02	< 0,02	< 0,02	< 0,02
3	Mercury (Hg)	mg/kg	0,50	0,31	0,41	0,17	0,78
<i>Vegetables</i>							

No	Metals	Unit	National Standards	Sampel A	Sampel B	Sampel C	Sampel D
1	Lead (Pb)	mg/kg	0,20	< 0,10	< 0,10	< 0,10	< 0,10
2	Cadmium (Cd)	mg/kg	0,05	< 0,02	< 0,02	< 0,02	< 0,02
3	Mercury (Hg)	mg/kg	0,03	0,042	< 0,02	< 0,02	< 0,02

The concentrations of heavy metals in vegetable samples were determined on spinach and kale collected from 2 locations (vegetable store and markets). The sample were coded with Sample A (spinach stalls), Sample B (kale stalls), Sample C (spinach market), and Sample D (kale market). The results showed that Pb and Cd concentration in vegetables were below the national standard at 0.20 mg/kg and 0.05 mg/kg, respectively. The mercury (Hg) concentration in vegetable samples B, C, and D were still below the national standard, however it exceeded the national standard for sample A (spinach from vegetables store) (Table 5).

The calculation of heavy metals intake and RQ calculation of lead (Pb), cadmium (Cd) and mercury (Hg) in river water, well water, fish and vegetables samples were presented in Table 6 and 7. The results showed that river water, well water, and vegetables consumption have RQ values below 1. These results indicated that river water, well water, and vegetables were still safe for consumption by the community. Meanwhile, fish samples showed different RQ values for each heavy metal. Lead (Pb) concentration in sample A (market tilapia) was still safe for consumption with RQ value below 1. While the other 3 samples have an RQ value > 1 for Sample B (market carp), Sample C (pond tilapia), and Sample D (pond carp). It indicated that sample B, C, and D were not safe for consumption by the community. The cadmium (Cd) content in 4 fish samples had an RQ value below 1, so that they were safe to consume by the community. Furthermore, the mercury (Hg) content in all fish samples had an RQ value above 1. This indicated that fish samples around the Citarum River were not safe for consumption.

Table 6. Intake of heavy metals from water, fish, and vegetables consumption

Samples	Intake		
	Lead (Pb)	Cadmium (Cd)	Mercury (Hg)
<i>River Water</i>			
Sampel A	0,00015625 mg/kg/day	0,0000625 mg/kg/day	0,00000625 mg/kg/day
Sampel B	0,00015625 mg/kg/day	0,0000625 mg/kg/day	0,00000625 mg/kg/day
Sampel C	0,00015625 mg/kg/day	0,0000625 mg/kg/day	0,00000625 mg/kg/day
<i>Well Water</i>			
Sampel A	0,00015625 mg/kg/day	0,0000625 mg/kg/day	0,00000625 mg/kg/day
Sampel B	0,00015625 mg/kg/day	0,0000625 mg/kg/day	0,00000625 mg/kg/day
Sampel C	0,00015625 mg/kg/day	0,0000625 mg/kg/day	0,00000625 mg/kg/day
<i>Fish</i>			
Sampel A	0,000390625 mg/kg/day	0,000078125 mg/kg/day	0,0012109375 mg/kg/day
Sampel B	0,000703125 mg/kg/day	0,000078125 mg/kg/day	0,0016015625 mg/kg/day
Sampel C	0,000703125 mg/kg/day	0,000078125 mg/kg/day	0,0006640625 mg/kg/day
Sampel D	0,00109375 mg/kg/day	0,000078125 mg/kg/day	0,003046875 mg/kg/day
<i>Vegetables</i>			
Sampel A	0,00015625 mg/kg/day	0,00003125 mg/kg/day	0,000065625 mg/kg/day
Sampel B	0,00015625 mg/kg/day	0,00003125 mg/kg/day	0,00003125 mg/kg/day
Sampel C	0,00015625 mg/kg/day	0,00003125 mg/kg/day	0,00003125 mg/kg/day
Sampel D	0,00015625 mg/kg/day	0,00003125 mg/kg/day	0,00003125 mg/kg/day

Table 7. Risk Quotient (RQ) Lead (Pb), Cadmium (Cd) and Mercury (Hg)

Samples	Lead (Pb)		Cadmium (Cd)		Mercury (Hg)	
	RQ	Result	RQ	Result	RQ	Result

Samples	Lead (Pb)		Cadmium (Cd)		Mercury (Hg)	
<i>River Water</i>						
Sampel A	0,317	Safe	0,125	Safe	0,01	Safe
Sampel B	0,317	Safe	0,125	Safe	0,01	Safe
Sampel C	0,317	Safe	0,125	Safe	0,01	Safe
<i>Well water</i>						
Sampel A	0,317	Safe	0,125	Safe	0,01	Safe
Sampel B	0,317	Safe	0,125	Safe	0,01	Safe
Sampel C	0,317	Safe	0,125	Safe	0,01	Safe
<i>Fish</i>						
Sampel A	0,792	Safe	0,156	Safe	2,12	Not Safe
Sampel B	1,426	Not Safe	0,156	Safe	2,80	Not Safe
Sampel C	1,426	Not Safe	0,156	Safe	1,15	Not Safe
Sampel D	2,218	Not Safe	0,156	Safe	5,26	Not Safe
<i>Vegetables</i>						
Sampel A	0,317	Safe	0,062	Safe	0,11	Safe
Sampel B	0,317	Safe	0,062	Safe	0,05	Safe
Sampel C	0,317	Safe	0,062	Safe	0,05	Safe
Sampel D	0,317	Safe	0,062	Safe	0,05	Safe

a. Health Risk Analysis of Cadmium (Cd)

Cadmium (Cd) in the environment is easily absorbed into the human body. As much as 5% of cadmium enters through the digestive tract, and accumulates in the human kidneys and liver. Cadmium has cumulative carcinogenic and toxic properties. The most affected organ by the ingestion of cadmium is the kidneys. Organ damage can occur due to the process of erythrocyte destruction, rhinitis, proteinuria, chronic bronchitis and emphysema. Symptoms of chronic poisoning due to contamination of cadmium is the excretion of micro-globulins in the urine as a result of damage to kidney function [30].

Based on the results of cadmium (Cd) concentration in 3 kinds of samples collected around the Citarum river, water (rivers and wells), fish and vegetables, showed that all samples were below the national standard. The results of the health risk analysis also showed the RQ value for Cd in all samples were still below 1. These results indicated that Cd in water, fish, and vegetables were still safe for consumption.

This result showed a different finding with the research conducted by Arief et al. [9] who determined the Cd concentration in Citarum river water at 4 stations. Samples were collected 3 times in each point. In the first test, all samples showed the same cadmium concentration at 0.003 mg/l. In the second observation, the cadmium concentration increased in all observation points ranging from 0.009 to 0.01 mg/l. In the third observation, the cadmium content showed similar results with the second observation around 0.007 – 0.01 mg/l. These results exceeded the maximum threshold for the cadmium (Cd) in river water (0.003 mg/l).

Rachmaningrum et al. [31] explained that the low concentration of Cd in Citarum river water might be caused by its characteristics to easily accumulate in the river sediments. This assumption was coherent with the data submitted by the Indonesian Environmental Control Agency in 2014. There were several industries established near the Citarum river consist of 5 plastic industries and 4 metal coating industries. There were also 13 electroplating industries and 2 electronics industries in Bandung Regency and 10 paint and metal coating industries in Cimahi City. These industries use cadmium as raw material in their production system. Thus, it was estimated that the industrial processing produces waste containing cadmium (Cd) discharged into the river. However, our results can also be used as a database for the success of the efforts made by the government in tackling Citarum river pollution.

b. Health Risk Analysis of Mercury (Hg)

Mercury (Hg) is one of the dangerous heavy metals and can be released naturally as a result of mineral reshuffling in nature by changes in weather/climate, wind, and water. Mercury is often found in marine fish and shellfish in the organic form. Mercury can enter the human body through the air containing metallic mercury vapor, or consuming food/drinks containing mercury. Inhalation of Hg vapor will be directly absorbed by alveolus into the blood system and quickly spread to other organs including the kidneys and brain. The accumulation of Hg in the body can disrupt the brain and nervous system, resulting in various symptoms such as shaking, irritability, loss of sensation and coordination, and memory difficulties [30].

In these results, the concentration of Hg in 3 kinds of samples collected around the Citarum River including water (rivers and wells), fish and vegetables, showed lower concentration. Almost all of samples were below the national standard. However, 2 samples, pond carp (sample D) and vegetable stores spinach (sample A), showed higher concentration than other samples at 0.78 mg/kg and 0.042 mg/kg, respectively. The pond carp might be exposed by Hg-contaminated water with low circulation of the pond water. So, the possibility of Hg absorption into the fish tissue might be higher. The Health Risk Analysis showed that the RQ value for Hg in fish was not safe for consumption in all samples. It should be concerned that Hg in fish is generally in methylmercury which the most toxic form. Methylmercury has been confirmed as the main cause of Minamata Disease occurred in 1950s in Japan.

c. Health Risk Analysis of Lead (Pb)

Lead (Pb) compounds are commonly used for glass making, PVC production, oil paints, oxidizing agents, fuels, etc. Pb can enter the human body through food consumption and inhalation. In the body, lead is processed like calcium. The first sites of absorption are the tissue membranes of plasma and blood. Furthermore, it is channeled to organs where calcium plays an important role such as teeth and bones. Pb is a particularly toxic to children because it is more easily absorbed by the developing body. About 99% of Pb can be excreted naturally from the adult body. However, only 32% can be excreted from children body. Excessive exposure to lead can inhibit growth, brain and nerve damage, kidney damage, nausea, hearing loss, headaches, joint pain, intellectual and behavioral disorders, loss of appetite, digestive disorders, increased of blood pressure, and reproductive disorders [30].

In this research, we found that almost all kinds of samples had concentrations below the national standard. However, only pond carp sample (0.28 mg/kg) exceeded the national standard. The calculation of the Health Risk Analysis showed that the RQ value for Pb in river water, well water, and vegetables samples were below 1, indicated that it is safe for consumption. Meanwhile, three fish samples were not safe for consumption even though in low concentration, but high consumption rate of fish can increase the risk to unsafe level in long period of time. This finding was also supported by health status data that 50% of the respondents experienced headaches and 15% of them experienced high blood pressure. Headaches and high blood pressure are correlated with the high Pb exposure in the body.

5. Conclusion

In conclusions, in this study, we found that fish samples were not safe for consumption by the residents around the upper Citarum River based on Hg and Pb concentration. The river water, well water, and vegetables were still safe for consumption by the residents due to low concentration of heavy metals in all samples. however, it should be noted that high rate of consumption can increase the potential health risk even though in low concentration in the food or water.

6. References

- [1] Humas KLKH. (2018). *KLHK Jelaskan Penanganan Pencemaran Sungai Citarum, Cisadane dan Ciujung*.
- [2] Sukiyah, E. (2017). *Sistem Informasi Geografis: Konsep dan Aplikasinya dalam Analisis Geomorfologi Kuantitatif*. Bandung: Unpad Press
- [3] Asian Development Bank. (2016). *Indonesia Country Water Assessment*. Metro Manila: Asian Development Bank.
- [4] Nursidika, P., Sugihartina, G., & Anwar, K. S. (2019). Kadar Merkuri pada Perairan Anak Sungai Citarum Daerah Industri II Cimahi. *Prosiding Rakernas V AIPTLMI*, 31–40.
- [5] Dewan Ketahanan Nasional. (2018). *Materi Presentasi yang Dibawakan oleh SESJEN WANTANAS - Dewan Ketahanan Nasional*.
- [6] CNN Indonesia. (2019). *1.286 Industri di Citarum Tak Terdata Punya Pengolahan Limbah*.
- [7] Gunawan. (2018). *Citarum Semakin Rusak*.
- [8] Miryanti, & Witono. (2015). *Pengembangan Adsorben Activated Fly Ash untuk Reduksi Ion Cu dan Cr dalam Limbah Cair Industri Tekstil*. Bandung: Universitas Katolik Parahyangan.
- [9] Arief, H. R., Dhahiyat, Y., Fakultas, A., Dan Ilmu, P., Unpad, K., Dosen, S., Perikanan, F., & Ilmu, D. (2012). Distribusi Kandungan Logam Berat Pb dan Cd pada Kolom Air dan Sedimen Daerah Aliran Sungai Citarum Hulu. *Jurnal Perikanan Dan Kelautan*, 3(3), 175–182.
- [10] Sudarningsih, & Bijaksana, S. (2016). Karakteristik Logam Berat dan Hubungannya Terhadap Parameter Magnetik Sedimen Sungai Citarum, Sebagai Studi Awal Kajian Kemagnetan Lingkungan di Sungai. *Seminar The 7th National Conference Paleo, Rock and Environmental Magnetism (PREM)*.
- [11] Said, N. I. (2010). Metode Penghilangan Logam Merkuri di dalam Air Limbah Industri. *Jurnal Air Indonesia (JAI)*, 6(1), 11–23.
- [12] Rice, K. M., Walker, E. M., Wu, M., Gillette, C., & Blough, E. R. (2014). Environmental Mercury and Its Toxic Effects. *Journal of Preventive Medicine and Public Health*, 47(2), 74–83.
- [13] Sharma, H., Rawal, N., & Mathew, B. B. (2015). The Characteristics, Toxicity and Effects of Cadmium. *International Journal of Nanotechnology and Nanoscience*, 3, 1–9.
- [14] Rahimzadeh, M. R., Rahimzadeh, M. R., Kazemi, S., & Moghadamnia, A. A. (2017). Cadmium toxicity and treatment: An update. *Caspian Journal of Internal Medicine*, 8(3), 135–145.
- [15] Waalkes, M. P. (2003). Cadmium Carcinogenesis. *Mutation Research - Fundamental and Molecular Mechanisms of Mutagenesis*, 533(1–2), 107–120.
- [16] Wani, A. L., Ara, A., & Usmani, J. A. (2015). Lead Toxicity: A Review. In *Interdisciplinary Toxicology* (Vol. 8, Issue 2, pp. 55–64). Slovak Toxicology Society. <https://doi.org/10.1515/intox-2015-0009>
- [17] Khotijah, K., Sjarifah, I., Mahendra, P. G. O., Widyaningsih, V., & Setyawan, H. (2017). The Effects of Lead (Pb) Exposure to Blood Pb Concentration and Hemoglobin Levels in Book Sellers and Street Vendors of Surakarta. *Jurnal Kesehatan Masyarakat*, 13(2), 286–290.
- [18] Taufik, B., Budiman, P., Dhahiyat, Y., Hamdani, H., Fakultas, A., Dan Ilmu, P., Unpad, K., Dosen, S., Perikanan, F., & Ilmu, D. (2012). Bioakumulasi Logam Berat Pb (Timbal) dan Cd (Kadmium) pada Daging Ikan yang Tertangkap di Sungai Citarum Hulu. *Jurnal Perikanan Dan Kelautan*, 3(4), 261–270.
- [19] Nasrun, D., Rinidar, R., & Armansyah, T. (2017). Cemar Logam Berat Timbal (Pb) pada Insang Ikan Cendro (*Tylosorus Crocodilus*) di Pesisir Krueng Raya Kabupaten Aceh Besar. *Jurnal Ilmiah Mahasiswa Veteriner*, 1(3).

- [20] Angraini, F., Anwar, A., & Risva, R. (2019). Analisis Risiko Kesehatan Lingkungan Non-Karsinogenik Tembaga pada Ikan Nila Keramba yang dikonsumsi dan dibudidayakan Masyarakat di Desa Jembayan. *Higiene: Jurnal Kesehatan Lingkungan*, 5(1), 14–21
- [21] Putra, D. S. P., Sulistiyani, & Budiyo. (2016). Analisis Risiko Kandungan Timah Hitam (Pb) pada Ikan Belanak di Sungai Tapak Kota Semarang. *Jurnal Kesehatan Masyarakat*, 4(5), 2356–3346.
- [22] Sundari, D., Hananto, M., & Suharjo. (2016, January 1). Kandungan Logam Berat dalam Bahan Pangan di Kawasan Industri Kilang Minyak, Dumai (Heavy Metal In Food Ingredients In Oil Refinery Industrial Area, Dumai). *Buletin Penelitian Sistem Kesehatan*.
- [23] Hananingtyas, I. (2017). Bahaya Kontaminasi Logam Berat Merkuri (Hg) dalam Ikan Laut dan Upaya Pencegahan Kontaminasi pada Manusia. *Al-Ard: Jurnal Teknik Lingkungan*, 2(2), 38–45.
- [24] Erianti, D., & Djelantik, S. (2019). Program Revitalisasi Sungai Citarum; Sebuah Analisis Strength, Weakness, Advocates, Adversaries (SWAA). *Jurnal Ilmu Administrasi: Media Pengembangan Ilmu Dan Praktek Administrasi*, 16(1), 81–96.
- [25] Iqbal, donny. (2018, February 26). *Limbah yang Tak Pernah Henti Meracuni Sungai Citarum (Bagian 1)*.
- [26] Chunhabundit, R. (2016). Cadmium Exposure and Potential Health Risk from Foods in Contaminated Area, Thailand. *Toxicological Research*, 32(1), 65–72.
- [27] Zhou, H., Yang, W. T., Zhou, X., Liu, L., Gu, J. F., Wang, W. L., Zou, J. L., Tian, T., Peng, P. Q., & Liao, B. H. (2016). Accumulation of Heavy Metals in Vegetable Species Planted in Contaminated Soils and the Health Risk Assessment. *International Journal of Environmental Research and Public Health*, 13(3)
- [28] Maurya, P. K., Malik, D. S., Yadav, K. K., Kumar, A., Kumar, S., & Kamyab, H. (2019). Bioaccumulation and Potential Sources of Heavy Metal Contamination in Fish Species in River Ganga Basin: Possible Human Health Risks Evaluation. *Toxicology Reports*, 6, 472–481.
- [29] MO, N. (2016). The Effects of Bioaccumulation of Heavy Metals on Fish Fin Over Two Years. *Journal of Fisheries & Livestock Production*, 4(2), 1–7.
- [30] Badan Standardisasi Nasional (BSN). (2009). *SNI 7387:2009 Batas Maksimum Cemar Logam Berat dalam Pangan*. Jakarta: Badan Standardisasi Nasional (BSN).
- [31] Rachmaningrum, M., Wardhani, E., & Pharmawati, K. (2015). Konsentrasi Logam Berat Kadmium (Cd) pada Perairan Sungai Citarum Hulu Segmen Dayeuhkolot-Nanjung. *Jurnal Reka Lingkungan*, 3(1), 1–11.
- [32] Wardani, E. (2018). Identifikasi Pencemaran Logam Berat Raksa di Sungai Citarum Hulu Jawa Barat. *Jurnal Teknik Kimia Indonesia*, 8(1), 17–23.
- [33] Connel, & Miller. (1995). *Kimia dan Etoksikologi Pencemaran, diterjemahkan oleh Koestoer, S.* Jakarta: Universitas Indonesia Press.
- [34] Besmanto, N., Cakrawati, C., Rizal, A., Sofwan, Nugroho, H., & Akib, C. R. (2012). *Pedoman Analisis Risiko Kesehatan Lingkungan*. Direktorat Jenderal PP dan PL, Kementerian Kesehatan Republik Indonesia.



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