p-ISSN 2086-6380
e-ISSN 2548-7949

Jurnal Ilmu Kesehatan Masyarakat, Nov2022, 13(3):321-333
DOI: https://doi.org/10.26553/jikm.2022.13.2.321-333
Available online at http://ejournal.fkm.unsri.ac.id/index.php/jikm

ENVIRONMENTAL HEALTH RISK ANALYSIS OF COPPER EXPOSURE TO CATFISH COMMONLY CONSUMED BY PEOPLE IN ULAK JERMUN VILLAGE, OGAN KOMERING ILIR

Sumihar Roberto Gultom, Imelda Gernauli Purba*, Inoy Trisnaini, Desri Maulina Sari, Hamzah Hasyim
Faculty of Public Health, Universitas Sriwijaya, Jl. Palembang-Prabumulih KM 32 Ogan Ilir, 30662, Indonesia

ABSTRACT

Catfish cultivated in rivers can be contaminated by heavy metals such as copper (Cu) which come from activities around the river. Copper exposure through the consumption of catfish will be harmful to health. This research aim to analyze the public health risks due to catfish consumption in Ulak Jermun Village, Ogan Komering Ilir. The design of study was cross sectional using the Environmental Health Risk Analysis method. The research respondents were 113 people with 5 samples of catfish taken from the river where the fish were cultivated. The analysis of heavy metal copper using the Atomic Absorption Spectrophotometer (AAS) method. The results showed copper contamination in catfish with an average concentration of 1.67 mg/kg. There were no respondents with RQ value > 1 for realtime non-carcinogenic health risks, but 11 people (9.7%) of respondents with RQ value > 1 for non-carcinogenic health risks in a lifetime. Meanwhile, for realtime carcinogenic exposure 34.5% had ECR values > 10^{-4} and 100% of respondents had ECR values > 10^{-4} for carcinogenic effects in lifetime. The conclusion was the people of Ulak Jermun are at risk of experiencing carcinogenic diseases due to copper exposure with the largest percentage of people aged> 32 years, female, and weighing ≤ 57 kg.

Keywords: *copper, environmental health risk assessment, catfish*

ABSTRAK

Ikan patin yang dibudidayakan di sungai dapat terkontaminasi oleh logam berat seperti tembaga (Cu) yang bersumber dari aktivitas di sekitar sungai. Pajanan tembaga melalui konsumsi ikan patin akan berbahaya bagi kesehatan. Penelitian ini bertujuan untuk menganalisis risiko kesehatan masyarakat akibat konsumsi ikan patin di Ulak di Desa Ulak Jermun, Ogan Komering Ilir. Desain penelitian ini *cross sectional* menggunakan metode Analisis Risiko Kesehatan Lingkungan. Responden penelitian 113 orang dengan 5 sampel ikan patin yang diambil dari sungai tempat ikan dibudidayakan. Analisis logam berat tembaga menggunakan metode Spektrofotometer Serapan Atom (SSA). Hasil penelitian menunjukkan terdapat cemaran tembaga pada ikan patin dengan konsentrasi rata-rata yaitu 1,67 mg/kg. Tidak terdapat responden yang memiliki nilai RQ > 1 untuk risiko kesehatan nonkarsinogenik *realtime*, namun ada 11 orang (9,7%) responden memiliki nilai RQ > 1 untuk risiko kesehatan nonkarsinogenik *lifetime*. Sedangkan untuk pajanan *realtime* karsinogenik 34,5% memiliki nilai ECR > 10^{-4} dan sebanyak 100% responden memiliki nilai ECR > 10^{-4} untuk efek karsinogenik *lifetime*. Kesimpulan penelitian ini adalah masyarakat Ulak Jermun berisiko mengalami penyakit karsinogenik akibat pajanan tembaga dengan persentase terbanyak adalah masyarakat yang berusia > 32 tahun, berjenis kelamin perempuan, dan memiliki berat badan ≤ 57 kg.

Kata kunci : tembaga, analisis risiko kesehatan lingkungan, ikan patin

* *Correspondence Address: Imelda G Purba, Faculty of Public Health, Universitas Sriwijaya, Jl. Palembang-Prabumulih KM 32 Ogan Ilir, 30662, Indonesia, E-mail: imelda@fkm.unsri.ac.id*

Received : September 8, 2022 Accepted : December 13, 2022 Published: December 20, 2022

Introduction

Indonesian people consume many types of fish including catfish. Catfish (*Pangasius sp.*) is one of the fishery commodities in the acceleration program industrialization of aquaculture commodity types with total production in 2012 of 651,000 tons.[1] The Ministry of Maritime Affairs and Fisheries data too shows an increase in the level of consumption of catfish in Indonesia in 2014-2017 increasing 21.9% with preference for catfish products consumed, namely fresh fish (76%) and preserved fish (15%). The Ministry of Maritime Affairs and Fisheries record in 2019 as mush as 47.4% of the total national production of catfish comes from South Sumatra and is a major producer biggest. In 2015, the national fish consumption level only reached 35.42 kilograms per capita per year. While the number of fish consumption in South Sumatra reached 37.89 kilograms per capita per year with the dominance of consumption of catfish.

Rivers and lakes as habitats for fish farming are very vulnerable to polluted, due to various human activities carried out in the vicinity.[2] The Ministry of Maritime Affairs and Fisheries in 2018 reported that one of the aquaculture development problems is pollution which has an impact on the quality of the aquaculture environment. Pollution of the aquatic environment can occur physically, chemically and biology caused by various things.[3] One of the causes of river and lake water pollution is heavy metals where many sources come from human activities through the disposal of industrial and household waste.[4]

One of the heavy metal contamination that can be found in catfish is heavy metal copper.[5] Sources of heavy metal contamination can come from waste industrial waste in upstream rivers, community domestic waste, the impact of agricultural activities and plantations around the river and fishing boat activities.[6] Live catfish and cultured for a long time allow catfish to be exposed to copper at a much higher concentration than that in river water. If consumed by the public in a fairly high frequency and for a long duration, it will become a risk factor for the community to be exposed to copper which is harmful to health.[7] Toxicity or poisoning of heavy metal copper will work when it has entered the body in large quantities or exceed the tolerance value of the organism concerned. When metal copper that enters the body has a high concentration, the copper is toxic in the body because it will be difficult to excrete.[8] Symptoms that arise in humans with acute copper poisoning are nausea, vomiting, abdominal pain, hemolysis (cell rupture), neutrophesis, seizures, and death.[9]

Komering River is one of the tributaries of the Musi River which is about 360 long kilometers with a width of between 200 - 300 meters. One of the villages that the Komering River flows through is Ulak Jermun Village, Sirah Island Padang District, Ogan Komering Ilir (OKI) Regency. During preliminary observations, the village turned out to be one of the centers for catfish breeding and cultivation in Ogan Komering Ilir Regency. Based on the data from previous studies the river which place for catfish cultivation in the village has contaminated with copper metal sourced from activities around the rivers. The copper exposure exceeding the quality standard will be harmful to the health of the people who consume fish catfish from the river.[10] The aim of this study was to analyze the public health risks due to catfish consumption in Ulak Jermun Village, Ogan Komering Ilir

Methods

This research was a descriptive with cross-sectional approachusing Environmental Health Risk Analysis (EHRA) method. The EHRA method is used to calculate the level of health risk in a population due to an exposure from the environment. Environmental Health Risk Analysis stages consist of Hazard Identification, Exposure Analysis, Dose-Response Analysis, and Risk Characterization. Hazard identification is a step in recognizing the type, nature and capabilities of risk agents copper which can cause adverse health effects. In the exposure analysis step, after knowing the value of concentration (C), rate of intake (R), frequency of exposure (fE), duration of exposure (Dt), body weight (Wb) and the time average (Tavg), then calculate the intake of the copper risk agent in the respondent's body using the following formula:

$$I = \frac{C \times R \times Fe \times Dt}{Wb \times Tavg}$$

The step of dose-response analysis is to determine the quantitative values of copper toxicity that expressed as a reference dose (RfD) for non-carcinogenic effects and Cancer Slope Factor (CSF) for carcinogenic effects. After obtaining intake (I) and dose response (RfD/SF) values, the next step is to characterize risks, both carcinogenic (RQ) and non-carcinogenic (ECR) risks using the following formula :

$$RQ = \frac{I}{Rfd} \text{(non-carcinogenic risk calculation);}$$

$$ECR = I \times SF \text{ (carcinogenic risk calculation)}$$

If there is an unsafe risk, then risk management steps are carried out by calculate and determine safe concentrations and safe intake rates using the formula:

$$C = \frac{\left(\frac{0{,}0001}{SF}\right) \times Wb \times 70 \times 365}{R \times Fe \times Dt} \text{(calculation of safe concentration)}$$

$$R = \frac{\left(\frac{0{,}0001}{SF}\right) \times Wb \times 70 \times 365}{C \times Fe \times Dt} \text{(calculation of safe intake rate)}$$

Several risk management approaches are the technological approach, the socio-economic approach and the institutional approach. The research sample consisted of 113 respondents by Proportional Random Sampling according to predetermined criteria. Criteria of respondent were living in RT 01 to RT 11 in Ulak Jermun, consuming catfish for at least the last 1 year from cultivation in Ulak Jermun Village, had no history of kidney and liver disease, and had never experienced hemolysis. Data collection through observation, interviews and direct questionnaire to the respondent community.The content of questionnaire were anthropometry (body weight), activity patterns consisting of intake rate and frequency of catfish consumption, length (years) of consuming catfish, to calculate Copper intake through consumption of catfish in respondents. Sampling of five catfish from the river where the cultivation was carried out used a purposive sampling technique, by taking fish samples with the provision of location points that have many catfish culture cages. Analysis of heavy metal copper in catfish was carried out through laboratory tests using the Atomic Absorption Spectrophotometer (AAS) method. The testing procedure based on the Indonesian National Standard (SNI) 2354.13:2014. The catfish has been prepared beforehand by taking the meat, finely chopped, drying in the oven, mashing until smooth, acidifying then adding the solution for testing and measuring using AAS. Data in the study analyzed descriptively with SPSS software as an application processing the data, only then from the calculation results can the risk be analyzed to see safe and unsafe risks to health, both non-carcinogenic and carcinogenic. This research had been declared ethical by the Ethics Committee of Health Research Public Health Faculty of Sriwijaya University based on certificate No: 325/UN9.1.10/KKE/2020.

Results

Univariate Analysis

1. Characteristics, Anthropometric Data and Activity Patterns of Respondents

Table 1. Frequency Distribution of Characteristics, Anthropometric Data and Activity Patterns of Respondents

Variable		Frequency	Percentage (%)	Mean	Median	Max	Min
Age							
	17-25	21	18,6				
	26-35	48	42,5	34,8	32	58	17
	36-45	23	20,4				
	46-55	20	17,7				
	56-65	1	0,8				
Gender							
	Male	52	46	-	-	-	-
	Female	61	54				
Weight							
	≤57	59	52,2	57,27	57	76	38
	>57	54	47,8				
Intake Rate							
	≤100	79	69,9	105,2	100	300	50
	>100	34	30,1				
Exposure Frequency							
	≤336	113	100	305,42	336	336	144
	>336	0	0				
Exposure Duration							
	≤5	57	50,4	6,54	5	20	2
	>5	56	49,6				

Based on table 1, the proportion of female respondents is slightly higher than male respondents. Respondents aged 17-32 years with the status of late adolescence to early adulthood have a percentage of 50.4% or 57 people and almost the same proportion as respondents aged 33-65 years who have the status of early adulthood to late elderly. The percentage of respondents with body weight 57 kg is slightly higher, namely 52.2% or 59 people than respondents with body weight >57 kg. For the variable rate of intake, respondents with an intake rate of 100 g have a larger proportion than respondents with an intake rate of >100. In addition, all respondents had an exposure frequency of 336 days in one year. The results also showed that the proportion of respondents with an exposure duration of 5 years was 50.4% or 57 respondents and almost the same for respondents with an exposure duration of >5 years.

Risk Analysis

1. Hazard Identification

Table 2. Copper Concentration on Catfish in Ulak Jermun Village

Catfish Sample	Number of Samples	Copper Concentration (mg/kg)	Threshold Value (mg/kg)
Sample 1	1	2,41	0,2
Sample 2	1	1,02	
Sample 3	1	1,32	
Sample 4	1	1,70	
Sample 5	1	1,91	
Average		**1,67**	

The concentration of copper (Cu) heavy metal contamination in catfish was measured using the AAS (Atomic Absorption Spectrophotometer) tool and method at the Faculty of Math and Science Laboratory, Sriwijaya University. Base on the table 2, the copper concentration in catfish has passed the specified threshold value, namely the average concentration value is 1.67 mg/kg and the highest copper contamination concentration is 2.41 mg/kg in sample 1, while the lowest concentration of copper contamination was in sample 2 with a concentration of 1.02 mg/kg.

2. Dose-Response Analysis

Table 3. Dose-Response of Copper

Chemical Agent	Dose-Response	Slope Factor
Copper	0,04 mg/kg/day	0,04 mg/kg/day

The value of Reference Dose (RfD) and Slope Factor (SF) are absolute determination values used to calculate how much intake of copper risk agents through the ingestion pathway that enters the body.

3. Exposure Analysis

Based on the results the average real-time non-carcinogenic copper intake is 0.0053 mg/kg×day with the lowest value being 0.0010 mg/kg×day and the highest intake value being 0.0174 mg/kg×day. The average lifetime non-carcinogenic copper intake is 0.0259 mg/kg×day with the lowest value being 0.0103 mg/kg×day and the largest value being 0.0678 mg/kg×day. For realtime carcinogenic copper intake, the average value is 0.0024 mg/kg×day with the lowest value being 0.0005 mg/kg×day and the highest value being 0.0076 mg/kg×day. Meanwhile the lifetime carcinogenic copper is 0.0112 mg/kg×day with the lowest value is 0.0043 mg/kg×day and the highest value is 0.0290 mg/kg×day.

4. Risk Characterization

The research result showed 100% respondents in Ulak Jermun Village have no non-carcinogenic risk for realtime exposure to copper (RQ >1), but there are 9.7% who have lifetime exposure to copper (RQ > 1). Meanwhile, for the real-time carcinogenic risk of exposure to copper, there is 34.5% (ECR >10^{-4}), and 100% of respondents have a lifetime carcinogenic risk of exposure to copper (ECR > 10^{-4}).

Table 4. Distribution by Age, Gender and Weight of Respondents at Realtime Carcinogenic Risk in Ulak Jermun Village

Variable		Frequency	Percentage (%)
Age (year)			
	17-25	4	10,3
	26-35	11	28,2
	36-45	10	25,6
	46-55	13	33,3
	56-65	1	2,6
	Total	39	100
Gender			
	Male	15	38
	Female	24	62
	Total	39	100
Weight (kg)			
	≤57	23	59
	>57	16	41
	Total	39	100

Table 4 shows respondents with a carcinogenic risk. The highest proportion was the age group 45-55 years (33.3%), followed by the age group 26-35 years (28.2%), the age group 36-45 years (25.6%), the age group 17-25 years (10.3%) and the smallest proportion is the age group of 55-65 years (2.6%). Judging from the gender variable, the highest percentage of respondents at risk of experiencing carcinogenic health problems are female respondents (62%), while the rest are male. Based on the weight variable, the highest percentage of respondents at risk of being carcinogenic is having a body weight of 57, as many as 59%.

5. Risk Management

This study did not determine safe concentrations and safe intake rates of non-carcinogenic because none of the respondents had a Risk Quotient (RQ) value of > 1. The results of risk management calculations for the safe concentration of carcinogenic copper (Cu) obtained the smallest value of 0.006 mg /kg, the largest value is 0.022 mg/kg, with an average value of 0.012 mg/kg. While the results of risk management calculations for the safe consumption rate of carcinogenic copper (Cu) obtained the smallest value is 33 gr/day, the largest value is 148 gr/day , with an average value of 81 gr/hr.

Discussion

Based on the results of laboratory tests using the AAS method, the copper concentration on catfish has exceeded the limit according to Indonesian National Standard (SNI), that the contamination of copper metal in fish consumed by humans, namely of 0.2 mg/kg. The route of entry of toxins in this study is through ingestion or the digestive tract into the body. Sample 1 with the highest concentration of copper could be due to the high concentration of copper in the river water, to be precise in the river sediment where cage 1 (one).

The river in cage 1 (one) area is slightly wider and forms a bend which makes the river flow in cage 1(one) calmer and wider than the river flow in other cages. This indirectly causes copper metal contamination that flows from the upstream of the river to accumulate more and be retained longer in the river sediments where cage 1 is located.[11] In addition, the location of one of the shipyard activities that has a high potential to cause copper pollution in river water is not far from cage1.[12] Therefore, the concentration of copper in river water, precisely in river sediments, is absorbed more and contaminates catfish in cages 1 which made the copper concentration in catfish from cage 1 higher than fish in other cages. The content of heavy metals in aquatic biota will usually increase from time to time because it is bioaccumulative, so aquatic biota be an indicator of metal pollution in waters.[13] Previous research explained that increased levels of heavy metals in river waters resulted in an increase in heavy metals in the bodies of fish and other biota in the river.[14] Previous study in Saguling Reservoir showed that the Pb in the body of catfish had exceeded the quality standard based on SNI 2009. Liver tissue damage in catfish in the Saguling Reservoir is swelling and necrosis. [15] Chronic exposure to Pb can lead to bioaccumulation at toxic concentrations in muscles. This is of particular concern because of the large consumption of fish muscle worldwide.[16]

The dose response risk analysis through the ingestion route to copper risk agents is 0.04 mg/kg×day and the slope factor (SF) value is 0.04 mg/kg×day and has a critical effect on liver damage (hepatic effect).[17] Cuprum can become toxic when it exceeds a certain threshold.[18] In infants and children, liver effects usually occur as one of three syndromes, Wilson's disease, cirrhosis, and idiopathic copper toxicosis.[19] After consumption copper (Cu) enters the liver, this will make the liver work inactively to detoxify increased levels of copper (Cu) in the body. This causes a negative impact on the nervous system, reproductive system, adrenal function, connective tissue, and decreased learning ability in newborns. If consumed in large quantities, Cu toxicity will cause severe vomiting, stomach pain, and urination. After that, it produces headaches and in fatal cases, seizures or paralysis can occur, resulting in death.[20] Copper (Cu) can cause disease in most cases if its concentration exceeds 30 mg/L. The blood copper thershold based on the provisions of World Health Organization is 0.8-1.2 mg/kg, while the toxicity value of copper ranges from 0.02-100 mg/kg.[21]

Factors that can influence the value of copper intake are weight of body (Wb) and time average (Tavg). The value of copper is directly proportional to lead concentration (C), intake rate (R), frequency of exposure (fE) and duration of exposure (Dt). The greater the weight a person has, the smaller the intake value received by that person.[22] Fat is one of the tissues in the body. People with a large body weight have more fat than those have a small weight. One of the reasons why toxins can accumulate in fat is because the function of fat is to store substances that absorbed by the intestines and liver, such as nutrients and toxins. Because of these storage factors, fat can prevent toxins from circulating too much in the circulatory system.[23]

In accordance with the results of questionnaires distributed directly to the public, it was found that people who consume catfish have a carcinogenic health risk. The length of time the respondent has consumed catfish (realtime), has an exposure frequency value ranging from 192 days-336 days in 1 year, and the duration of exposure is 4-20 years. Other people who do not have non-carcinogenic and carcinogenic risks, have an exposure frequency value of 144 days in 1 year with an exposure duration of 2-3 years. The consumption frequency value of people who do not have a health risk is smaller than that of people who have a risk of health problems. Based on the calculation results, the duration of exposure has the most influence on respondents who have health risks with non-carcinogenic and carcinogenic effects with the length of consumption of catfish which is estimated to be up to 30 years in the future (lifetime). Intake projections are carried out until the next 30th year, where the results show that the longer the duration of catfish consumption, the greater the value of copper (Cu) intake in the respondent's body. This is in line with previous research that the longer the duration of exposure, the greater the toxic effect of a metal on health.[24]

Data on 39 respondents who had real-time carcinogenic health risks through consumption of catfish exposed to copper (Cu) were cross tabulated with age, sex and weight variables. Respondents who have a carcinogenic risk and are aged above the cut of point value of the respondent, which is 32 years are 69% or 27 people from 39 respondents, while the remaining 12 people are less than or equal to 32 years. The age group most at risk is early adulthood to the elderly (>32 years). While respondents in their late teens to early adulthood (17 years-32 years) are less likely to experience risk. This means that a person's risk of developing carcinogenic diseases through consumption of catfish exposed to copper (Cu) is in line with increasing age, which is due to the increasing frequency and duration of exposure.[25]

The highest percentage of respondents who are at risk of experiencing carcinogenic health problems are women, namely 62% or 24 of 39 people, while the remaining 38% or 15 more people are male. Looking at the facts in the field through direct observation, this can be because female respondents spend most of their time at home taking care of the household, in contrast to male respondents who spend more time outside the home and making food menus. In particular, the side dishes are becoming more varied, so that the catfish cooked at home will be consumed more by women.

Based on the weight variable, the highest percentage of respondents who are at risk of being carcinogenic is having a body weight of 57, as many as 59% or 23 of 39 people. This can be caused by fat in respondents who weigh 57 less than respondents who weigh > 57, whereas fat can play a role in preventing the spread of copper (Cu) in the body. In accordance with previous studies that one of the reasons why toxins or toxins can accumulate in fat is because the function of fat itself is as a store for substances that are absorbed by the intestine and liver, such as nutrients and toxins. Therefore, fat can prevent toxins from circulating too much in the circulatory system.[26] The results of the study show that not all people with a residual period of time consuming catfish (realtime) have a copper intake value that exceeds the threshold value, but when viewed from the calculation of the length of consumption of catfish which is estimated to be up to 30 years in the future. The results show that the whole community has a risk value that exceeds the threshold value. This means that although the Risk Quetion (RQ) or Excess Cancer Risk (ECR) value does not exceed the threshold, if it is estimated for the next 30 years it can harm the body. Previous study showed that people who consume shellfish exposed to Plumbum, 91.3% of them are at risk of experiencing non-carcinogenic health risks.[27] Other study showed that the woman of chlid bearing age who have a frequency of consumption seafood category frequent (≥ 4 times inone week) has a risk of 2.1 times greater have blood Pb levels not normal compared to women aged fertile who have a frequency of consumption rare seafood category (< 4 times in one week).[28]

To determine the safe concentration of catfish cultured in rivers, the smallest value of each safe concentration value is calculated for both non-carcinogenic and carcinogenic safe concentrations. The smallest value of safe carcinogenic concentration is determined as the maximum value of copper contamination in catfish, which is 0.006 mg/kg, meaning that people can only consume catfish with a maximum concentration of copper contamination 0.006 mg/kg. This is done so that all people who consume catfish can avoid the risk of non-carcinogenic and carcinogenic diseases. The intake rate of catfish consumption also has an important role in assessing the risk of disease due to copper poisoning. After the calculation, the value of the safe intake rate is obtained for each community that has a risk value. What can be done is to reduce the daily consumption rate of catfish. However, in contrast to the safe concentration value which uses the smallest value, in determining the safe intake rate, each community has a different value that must be adjusted to body weight and consumption frequency habits.[29]

Conclusion

The community of Ulak Jermun Village does not experience the risk of non-carcinogenic (realtime) health problems because no one has an RQ value> 1, but there are 11 people (9.7%) who have a lifetime non-carcinogenic health risk. For real-time carcinogenic exposure, 39 people (34.5%) of 113 respondents were at risk for carcinogenic diseases and 100% of respondents had a lifetime risk of causing carcinogenic effects.The percentage of people who experience carcinogenic health risks are more than 32 years old, namely 69% or 27 people from 39 respondents, more are female, which is 62% or 24 of 39 female respondents and more weight 57, namely 59% or 23 people from 39 respondents.Possible risk management efforts are setting a safe limit for the maximum concentration of copper contamination, which is 0.006 mg/kg, and reducing each intake rate or total consumption of catfish in the range of 33 g/day to 148 g/day for each people who are at risk of being unsafe for carcinogenic diseases.

Acknowledgement

The authors thank the village head of Ulak Jermun and the community who assisted in conducting the research.

Funding

No research grants

Conflict of Interest

There is no conflict of interest

References

1. Perikanan KK. Kelautan dan Perikanan dalam angka 2014. Pusat Data Statistik dan Informasi Kementerian Kelautan Perikanan Jakarta. 2014;100.
2. Anggraini ACW. Arahan Optimasi Produksi Perikanan Budidaya Bandeng Melalui Konsep Community Based Natural Resource Management (Cbnrm) Pada Kecamatan Manyar Kabupaten Gresik: Institut Teknologi Sepuluh Nopember; 2016.

3. Hamuna B, Tanjung RH, MAury H. Kajian kualitas air laut dan indeks pencemaran berdasarkan parameter fisika-kimia di perairan Distrik Depapre, Jayapura. 2018.
4. Dewi NK. Biomarker pada ikan sebagai alat monitoring pencemaran logam berat kadmium, timbal dan merkuri di perairan Kaligarang Semarang: Program Doktor Ilmu Lingkungan; 2012.
5. Ariansya KA, Yuliati K, RJ SH. Analisis Kandungan Logam Berat (Pb, Hg, Cu dan As) Pada Kerupuk Kemplang Di Desa Tebing Gerinting Utara, Kecamatan Indralaya Selatan, Kabupaten Ogan Ilir. Jurnal FishtecH. 2012;1(1):69-77.
6. Filipus RA, Purwiyanto AIS, Agustriani F. Bioakumulasi Logam Berat Tembaga (Cu) pada Kerang darah (Anadara granosa) di Perairan Muara Sungai Lumpur Kabupaten Ogan Komering Ilir Sumatera Selatan. Maspari Journal: Marine Science Research. 2018;10(2):131-140.
7. Safitri FZ. Tingkat Efek Kesehatan Lingkungan Kandungan Logam Berat Kadmium (Cd) dalam Kerang Hijau (Perna viridis) yang Dikonsumsi Masyarakat Kaliadem Muara Angke Jakarta Utara Tahun 2015. 2015.
8. Rosahada AD, Budiyono B, Dewanti nay. Biokonsentrasi Logam Berat Tembaga (Cu) dan Pola Konsumsi Ikan Mujair Di Wilayah Danau Rawapening. Jurnal Kesehatan Masyarakat (e-Journal). 2018;6(6):1-7.
9. Dian Ratnasari N. Penurunan Kadar Tembaga (Cu) pada Limbah Cair Industri Elektroplating Menggunakan Cangkang Telur Ayam Potong Teraktivasi Termal (Studi di Industri Elektroplating X di Kabupaten Jember). 2019.
10. Mutoharoh IL. Bioakumulasi paparan logam berat Cadmium (Cd) pada daging ikan Lele (Clarias sp.): UIN Sunan Ampel Surabaya; 2019.
11. Atmaja DM. Konservasi Fungsi Danau Beratan Berbasis Sistem Informasi Geografi di Dataran Tinggi Bedugul Bali: UNS (Sebelas Maret University); 2019.
12. Amelia F, Ismarti I, Ramses R, Rozirwan R. Biokonsentrasi Faktor Logam Berat pada Kerang dari Perairan Batam, Kepulauan Riau, Indonesia. EduChemia (Jurnal Kimia dan Pendidikan). 2019;4(2):152-163.
13. Martuti NKT, editor Kandungan logam berat cu dalam ikan bandeng, studi kasus di tambak wilayah Tapak Semarang. Seminar Nasional Pengelolaan Sumberdaya Alam dan Lingkungan; 2012.

14. Bariatik B. Penetapan Kadar Timbal (Pb) pada Ikan Bader (Barbonymus Gonionotus) dengan Perendaman Filtrat Jeruk Nipis (Citrus aurantifolia)(Studi di Pasar Legi Kota Jombang): STIKES Insan Cendekia Medika Jombang; 2017.
15. Nuraeni A, Samosir A, Sulistiono S. Akumulasi Logam Berat Timbal (Pb) pada Hati Ikan patin Pangasius Djambal) di Waduk Saguling, Jawa Barat. Jurnal Teknologi Perikanan dan Kelautan. 2021;12(2):113-123.
16. Latif M, Zahoor M, Muhammad A, Naz S, Kamran A, Ullah R, et al. Bioaccumulation of lead in different organs of Ctenopharyngodon Idella (grass fish) and Tor putitora (Mahseer) fish. Brazilian Journal of Biology. 2022;84.
17. Suphia Rahmawati ST M. Estimasi Intake Logam Berat pada Konsumsi Ikan dari Sungai Code, Yogyakarta dan Risiko Kesehatannya. 2020.
18. Asih AYP, Muhith A, Fasya AHZ, hermanto H, editors. Cu (Cuprum) Pollution Effect from Shrimp Processing. International Conference Earth Science & Energy 2020: IOP Publishing.
19. Adedeji O, Olayinka O, Tope-Ajayi O, Adekoya A. Assessing spatial distribution, potential ecological and human health risks of soil heavy metals contamination around a Trailer Park in Nigeria. Scientific African. 2020;10:e00650.
20. Anant JK, Inchulkar S, Bhagat S. An overview of copper toxicity relevance to public health. European Journal of Pharmaceutical and Medical Research. 2018;5(11):232-237.
21. Edokpayi JN, Odiyo JO, Olasoji SO. Assessment of heavy metal contamination of Dzindi river, in Limpopo Province, South Africa. Int J Nat Sci Res. 2014;2(10):185-194.
22. Faisya AF, Putri DA, Ardillah Y. Analisis risiko kesehatan lingkungan paparan hidrogen sulfida (H2S) dan ammonia (NH3) pada masyarakat wilayah TPA Sukawinatan Kota Palembang Tahun 2018. Jurnal Kesehatan Lingkungan Indonesia. 2019;18(2):126-134.
23. Wijiarti K, Darundiati YH, Dewanti NAY. Analisis Risiko Kesehatan Lingkungan Paparan Sulfur Dioksida (SO2) Udara Ambien Pada Pedagang Kaki Lima Di Terminal Bus Pulogadung, Jakarta Timur. Jurnal Kesehatan Masyarakat (Undip). 2016;4(4):983-991.
24. Alwi J, Yasnani Y. Analisis Risiko Kesehatan Lingkungan Akibat Pajanan Timbal (Pb) pada Masyarakat yang Mengonsumsi Kerang Kalandue (Polymesoda Erosa) dari

Tambak Sekitar Sungai Wanggu dan Muara Teluk Kendari. (Jurnal Ilmiah Mahasiswa Kesehatan Masyarakat). 2016;1(3).
25. Erdinur E, Muslim B, Zicof E. Risiko Pajanan Bahan Pencemar Tterhadap Pekerja Pengecatan Mobil Ddi PT. Steelindo Motor Kota Padang. Jurnal Sehat Mandiri. 2021;16(1):105-114;https://doi.org/10.33761/jsm.v16i1.330.
26. Tandra H. Segala sesuatu yang harus anda ketahui tentang diabetes: Gramedia Pustaka Utama; 2017.
27. Fatmayani I, Gafur A. Analisis Risiko Kesehatan Lingkungan Pajanan Timbal Dan Kromium Pada Masyarakat Yang Mengonsumsi Kerang Marcia hiantina Di Perairan Selat Makassar. Window of Public Health Journal. 2022;6(6):1831-1842.
28. Kusumastuti D, Setiani O, Joko T. Analisis Frekuensi Konsumsi Makanan Laut dan Kandungan Logam Berat Pb dalam Darah Wanita Usia Subur (Wus) di Wilayah Kerja Puskesmas Bandarharjo. Jurnal Kesehatan Masyarakat (Undip). 2020;8(5):687-693;https://doi.org/10.14710/jkm.v8i5.27988.
29. Afifah N. Faktor Risiko yang Berhubungan dengan Kejadian Berat Badan Lahir Rendah (BBLR) Studi Kasus di Kecamatan Wanasari Kabupaten Brebes: Universitas Negeri Semarang; 2016.