Nat. Volatiles & Essent. Oils, 2021; 8(6): 1768-1778

Environmental Health Risk Assessment Due To Copper (Cu) And Pm_{10} Exposure On The Family Member Of Goldsmith's Community In Molimongan Village Makassar

Eva Soelastri Harahap[1] , Anwar Mallongi[1] , Masni[2] , Hasanuddin Ishak[1] , Erni Ibrahim[1], Yahya Thamrin[3]

[1]Department of Environmenta lHealth, Faculty of PublicHealth, Hasanuddin University, Indonesia

[2]Department of Statistic, Faculty of Public Health, Hasanuddin University, Indonesia

[3]Department of Occupational and Safety, Faculty of Public Health, Hasanuddin University, Indonesia

Abstract

Current development is always linear with the increase of life and technology needs. Jewellery turns to be one of the lives needs which customers keep growing over time. However, those engaged in jewellery production are prone to health problems due to exposure to toxic and hazardous materials in their work. This research employed an environmental health risk analysis applying an agent-based approach towards the source materials of exposure; thus, the emerging risks can be calculated, and the risk management can be executed. The process of environmental risk analysis includes hazard identification, dose-response analysis, hazard characterization, and risk management. This research involved 30 whom are the spouses/family members of the Satando's goldsmiths. The risk analysis was executed by calculating the Real-time and Lifetime RQ and THQ. By applying the ICP method, the results suggested that Cu exposure was detected in the respondents' hair, whereas PM10 concentration was discovered in the respondents' workshops. The results indicated high concentrations of Cu in the respondent's hair with the mean of 39.34 μg/g. Real-time RQ calculation suggested that 6.6% had an RQ value greater than 1, and it increased after lifetime calculation with RQ value greater than 1 in 10%. Meanwhile, the mean concentration of PM10 reached 38 g/m3, and the results of the RQ calculation in the sample did not indicate any potential risk. Furthermore, the THQ calculation on both parameters resulted in a THQ value of less than 1, indicating there was no target level of potential risk due to Cu and PM10 exposure in the gold jewellery craftsmen community. In Conclusion, RQ and THQ generally dependent on the concentration of agent and human behavior, reducing the concentration of Cu in the hair and maintaining the similar condition are subject to prevent further risk in the community.

Keywords: Environment, Risk, Toxicant, Copper, Particulate Matter, Risk Assessment

Introduction

The changing times are a condition that is always followed by technological developments and increasing needs and the fulfillment of these needs sometimes causes social, economic, and environmental problems.

According to Manik (2018), Jewelry is one of the needs of society. Jewelry can be interpreted as an object used to make up or beautify an individual or given as a gift to someone else (Diantoro 2010)

In this regard, according to Soim (1970), in the production process, in addition to using the precious metal, gold (Au), as the main raw material for the main product, a mixture of various toxic and hazardous chemicals (B3) is also used. Copper (Cu) in the form of plates is used to precipitate and separate silver (Ag) into silver oxide precipitates during the recycling process (Setiani et al.,2016)

Copper is one of the materials used in the production of gold jewelry. (Palar 2012). Copper is an essential element in the human immune system but can also cause allergies. Clinical symptoms of copper poisoning can cause epigastric pain, anorexia, hematuria, dysuria, back pain, metallic taste, convulsions, and coma (Soedarto 2013)

In humans, the main poisoning effect caused by exposure to Cu dust or fumes is the occurrence of disturbances in the upper respiratory tract. The effect of poisoning caused by exposure to Cu dust or fumes is the occurrence of atrophic damage to the mucous membranes lining the nose. This damage is the result of the combined irritating properties of the Cu dust or fumes (Palar 2012). According to CTESA 2007 the average concentration of Cu in human hair is 11.3 mg/kg (Zhou et al. 2016)

In the gold jewelry production process, exposure to inorganic chemicals can occur during the steps of molding, casting, filling, polishing and plating gold jewelry (Choudhari et al. 2014). Most exposures tend to accumulate chronically as goldsmiths are exposed every day at work. Furthermore, under conditions of continuous exposure, not all metals that enter the body will be removed. Conversely, exposure will accumulate in body tissues such as hair and bones (ATSDR 2004) and can cause toxic effects and disease (Abidin et al. 2015).

Heavy metals are associated with inhaled dust particles. Heavy metals in dust particles having a size of below 10 µm can be absorbed very deeply in the lungs, can settle in the lungs, and cannot be removed easily through exhalation and inhalation which can be harmful to human health.

The entry portal per inhalation is the entry of xenobiotics through the respiratory tract. This entry portal makes it easier for gas to enter the blood circulation. The distribution of substances occurs in various environmental compartments and their interphases; this xenobiotic transportation can enter the human body and cause health problems if it occurs simultaneously and in concentrations that exceed the threshold (Mallongi 2019).

PM10 polluted air can cause health problems to humans. Therefore, the government determines the allowable limit of exposure to PM10 in the Regulation of the state minister for the Environment Number 12 of 2010 that the ambient air quality standard for PM10 is 20 ug/m3 for the annual average and 50 ug/m3 for the daily average (Ministry of Environment 2010) and pursuant to PERMENKES 1077 of 2001 the quality standard for PM10 is 70 ug/m3.

Makassar is known as one of the cities with the highest gold production and is a center for the gold jewelry trade in Indonesia. This gold jewelry is made by traditional and modern experts known as pade'de or goldsmiths. Goldsmiths are scattered in several places in Makassar City and are found in several subdistricts, namely Wajo Subdistrict, Mangala Subdistrict and Ujung Pandang Subdistrict. However, only Mangala and Wajo subdistricts are registered based on data from the Industry and Trade (PERINDAG) Office (Suhelmi 2018).

In this regard, gold production in Wajo Subdistrict is carried out by the Satando community, named after the road, located in Malimongan Village, Wajo Subdistrict. This community has been established since 2008 and has become a forum for goldsmiths to market their jewelry. However, attention to health and good work environment is still very low among goldsmiths in that community.

Methods

Research Design

This study uses a cross-sectional design with the Environmental Health Risk Analysis method in calculating the risks that have the probability of arising from exposure to Cu and PM10 to family members of the Malimongan goldsmith community in Makassar. Risk analysis is a way to determine the extent to which a hazardous material affects the quality of human health or the environment (Mallongi 2019). Risk analysis can also be interpreted as a step in calculating or estimating the risk to a population after exposure to a particular agent (US EPA 2012). Approaches that can be applied to risk analysis studies can be in the form of disease oriented and agent-oriented approaches. For which the disease-oriented approach assesses risk based on the effects that already exist or appear in the sufferer. Meanwhile, the agent-oriented approach observes exposure pathways such as inhalation, ingestion, and absorption without taking into account the effects that have occurred (Soemirat 2013). The calculation of RQ and THQ is done using the following equation (ATSDR 2004)

$$\times 10^{-3}$$

RQ	:	Risk Quotient
Ink	:	Intake (mg/kg/day)
RfC	:	Reference Dose for Inhalation
THQ	:	Target Hazard Quotient
EF	:	the exposure frequency (days)
ED	:	the exposure duration (year)
R	:	Inhalation rate (m3/day)
W	:	the body weight (kg)
AT	:	the averaging time (days)

Population and Sample

The population in this study is goldsmiths' family members who live with goldsmiths in the same house to which a workshop for work for goldsmiths is attached. The total sample size are 30 people, and the research was conducted from December 2020 to June 2021.

Data Collection and Analysis

Primary data were obtained through interviews using questionnaires to respondents and taking biological samples (hair) and environmental samples (indoor PM10 concentrations). Examination of hair samples was carried out at the Health Laboratory Center (BBLK) for Makassar using the Inductively Couplet Plasma (ICP-MS) method and PM10 concentration analysis was carried out at the Disease Control and Environmental Health Laboratory (BTKLPP) of Makassar using the Environmental Particulate Air Monitor (EPAM-5000).

The total sample of hair is 30 respondents and air quality inspections are conducted at 30 location points which are goldsmiths' workshops.

Results and Discussion

Characteristics of respondents

Malimongan Village is part of the administrative map of Wajo Subdistrict. Geographically, this village is located at 5° 6'- 5°7' south latitude and 119°24'50" - 119°24'842" north latitude. The average annual rainfall is 229 mm3 and the average temperature is 28.8°C. The area of the Malimongan village is 0.41 km2 with 4578 inhabitants. These inhabitants are spread over 6 RWs in 27 RTs with a total number of 926 households. Jalan Satando is located in the Malimongan village and is one of the locations playing a role in the silver and gold industry in South Sulawesi (BPS Makassar City, 2019)

The inhabitants residing at Jalan Satando have their own uniqueness, where they work as goldsmiths from generation to generation. In the 1980s to early 2000s this location played a very important role for the jewelry commodity in Makassar. So that almost 100% of the population at Jalan Satando Malimongan work as goldsmiths. Jewelry processing is performed traditionally so that the community is famous for the quality and uniqueness of the jewelry designs they produce. Until 2020, several goldsmiths are concentrated in locations located in RW2 and at Jalan Satando. Goldsmiths who live and work in this area are members of a community called the Satando community. Traditional goldsmiths in the Malimongan village are concentrated in RW 2 and reside at Jalan Satando which is finally used as the name of the goldsmith community. The community has worked from generation to generation using traditional methods. Several studies to determine the health and environmental health problems that may occur have been conducted. Goldsmiths' family members who live side by side with the goldsmiths for many years may have health risks caused by exposure to hazardous materials over a period of time.

Concentration of Cu and PM10

Table 1. Concentration of Cu and PM10

No.	Sample No.	Concentration of Cu in goldsmiths (mg/kg)	Sample No.	Concentration of PM10 (µg/n3)
1	H1	68.36	Location Point 1	0.042
2	H2	17.13	Location Point 2	0.031
3	H3	101.86	Location Point 3	0.021
4	H4	26.58	Location Point 4	0.032
5	H5	29.68	Location Point 5	0.026
6	H6	26.39	Location Point 6	0.043
7	H7	9.97	Location Point 7	0.015
8	H8	21.58	Location Point 8	0.022
9	H9	14.83	Location Point 9	0.028
10	H10	63.74	Location Point 10	0.031
11	H11	28.99	Location Point 11	0.032
12	H12	13.74	Location Point 12	0.024
13	H13	23.19	Location Point 13	0.015
14	H14	96.22	Location Point 14	0.022

15	H15	7.80	Location Point 15	0.028
16	H16	12.07	Location Point 16	0.031
17	H17	52.57	Location Point 17	0.068
18	H18	41.91	Location Point 18	0.040
19	H19	35.36	Location Point 19	0.032
20	H20	90.61	Location Point 20	0.049
21	H21	22.48	Location Point 21	0.025
22	H22	75.55	Location Point 22	0.044
23	H23	21.09	Location Point 23	0.068
24	H24	9.83	Location Point 24	0.040
25	H25	74.41	Location Point 25	0.041
26	H26	27.04	Location Point 26	0.022
27	H27	7.60	Location Point 27	0.030
28	H28	56.04	Location Point 28	0.050
29	H29	33.93	Location Point 29	0.141
30	H30	69.65	Location Point 30	0.032
Quality Standard		**11.30**		**0.070**
Mean		**39.34**		**0.038**
Median		**28.01**		**0.032**
Minimum		**7.60**		**0.015**
Maximum		**101.86**		**0.141**

Table 1 shows the concentrations of Cu and PM10. The concentration of Cu in the hair of non goldsmiths or of goldsmiths' family members or partners shows that the lowest concentration of Cu in hair is 7.60 mg/kg and the highest concentration is 101.86 mg/kg. The mean and median in this respondent group are 39.34 mg/kg and 28.01 mg/kg. 26 respondents (86.6%) have a concentration value exceeding the normal average value of Cu concentration in human hair as determined by the Trace Elements Science Association of China (CTESA) which is 11.3 mg/kg.

Table 2. Respondents' activity patterns

Characteristic	**Mean**	**Median**	**Mode**	**Min**	**Max**
Length of Exposure (tE) (hour/day)	2.57	3	3	1	3
Frequency of Exposure (fE) (day/year)	353.8	357.5	365	314	365
Duration of Exposure (Dt) (year)	19.37	19	10	4	52

The investigation of PM10 concentration is conducted in 30 goldsmiths' workshops/ workspace. Based on the results of observations, all workshops found in the Satando community are in the same location as the house or attached to the house. As shown in table 2, the lowest concentration is at location 7 with a PM10 concentration value of 0.015 mg/m3, and the highest concentration value of 0.141 mg/m3 is at location 29. Based on the indoor air quality standard set out in PERMENKES No 1077 of 2001 on Guidelines for Indoor Air Sanitization, which is 70 ug/m3, only 1 workshop located at location point 29 exceeds the specified quality standard.

Environmental Health Risk Analysis

Exposure Analysis

Exposure analysis is conducted to determine the intake due to exposure to hazardous materials. The duration of exposure experienced by the respondents is 2.57 hours/day on average with the shortest exposure duration of one hour and 3 hours for the longest exposure experienced by the respondents in one day. Meanwhile for the frequency of exposure (fE), the respondents have 353.8 days/year on average with the shortest exposure frequency of 314 days/year and the longest exposure frequency of 365 days. Furthermore, respondents who are not goldsmiths have an average exposure duration of 19.37 years with the shortest duration of 4 years and the longest duration of 52 years.

Risk analysis

The risk level analysis is conducted by making a calculation of Risk Question and Target Hazard Question. Copper is a metal that has not been included in the group that cannot cause cancer, so the calculation is done by dividing the intake by the RfC or the reference dose for inhalation. Since copper does not yet have a defined RfC, the calculation of the RfC of copper is done with I = RfC under conditions of tE 24 hours/day, fE 350 days/year and Wb 70 kg, bringing the RfC for Cu to 3.08 mg/kg/day.

Next is the calculation of the PM10 intake value by multiplying the PM10 concentration value in the quality of goldsmiths' and non-goldsmiths' indoor workshops by the R value that has been determined by (US EPA 2004) which is 0.83 m3/hour and the values of fE, tE and Dt obtained from interviews with respondents. Furthermore, this value is divided by the tavg (real time and lifetime) value and the respondent's body weight, bringing the RfC value of PM10 to 0.019 mg/kg/day.

Table 3. RQ and THQ due to exposure to Cu

Calculation	Mean	Median	Mode	Min	Max	> 1	< 1
RQ	0.29	0.13	0.16	0.16	1.49	2	28
THQ	0.00017	0.00012	0.00002	0.00002	0.0005	0	0

Based on table 3, from the results of the realtime calculation of RQ and THQ due to exposure to Cu in respondents it is known that the average value of RQ is 0.29, the minimum value of RQ is 0.16 and the maximum value of RQ is 1.49. Overall, there are 2 respondents who have a risk or RQ value > 1 (6.7%). The calculation of the THQ value shows that the average THQ of the respondents is 0.00017 in which the lowest THQ value is 0.00002 and the highest THQ value is 0.0005. All respondents (100%) have no risk of target hazard due to exposure to Cu.

Furthermore, the calculation of the RQ and THQ values due to exposure to PM10 can be seen in table 4. According to the data presented, the average RQ value is 0.04 with the lowest RQ value being 0.004 and the highest RQ value being 0.198 and all respondents have the RQ < 1 (100%), no risk. The calculation of the THQ value shows that the average THQ value is 2.50E-04 with the smallest THQ value being 9.50E-05 and the largest TQH value being 9.03E-04. The results of the THQ calculation show that there is no target risk that can arise due to exposure to PM10 in all respondents.

Risk management

Risk management is the means taken to cause the risks arising from exposure to hazards in the environment not to affect human health. The processes involved in this activity include identification, evaluation, selection of options and implementation of an activity that can reduce risks to both human and ecosystem health (Soemirat 2013). Reducing the concentration of agents is one way that can be done to reduce risk. According to (Rahman 2007) the way to get an intake value which is small or with a reference dose of toxicity is to manipulate the exposure values contained in the equation used in calculating the RQ value.

Characteristics of Respondents

A goldsmith is a profession having a lot of contact with chemicals in the work process. The use of chemicals is sometimes not followed by an adequate educational background. The results of field observations show that almost half (46.7%) of the goldsmiths only graduated from elementary school and only 1 respondent has a university/higher education classification (3.3%). In general, all respondents were born and are living in the research location and are goldsmiths' children or successors to the family's gold or silver craft business.

Risk analysis

Exposure to pollutants in the environment can affect human health. The living and working environment should be safe and far from hazardous substances that can affect an individual's health (Khullar and Gupta 2017). Respiratory and cardiovascular disorders are one of the diseases that can arise due to exposure to PM10 (Zhang et al. 2018) and chronic exposure to copper can cause digestive problems (Araya et al.,2007)

Copper plays an important role as an essential substance in animals and humans. The work process performed by goldsmiths in the workplace allows the formation of Cu particulate and Cu fumes from combustion/smelting in the production process. High concentrations of Cu in serum have been associated with an increased risk of heart disease in humans but the justification for this association is still unclear and is not exactly measurable (Angelova et al. 2011).

According to Alet et al. (1982), copper is an important element for humans due to several protein components that are needed in life; a lack of this can contribute to bone formation disorders in humans. Meanwhile, chronic exposure to Cu can cause several diseases, one of which is Wilson's disease. For short exposures, effects of this exposure will be seen in the stomach and intestines (Araya et al. 2007).

Another problem that arises because of exposure to Cu is Metal Fume Fever (MFF). This disease can be interpreted as one of the diseases related to the work performed due to inhalation of metal oxides or compounds containing metal. The main sources of exposure are related to the work performed including the smelting, heating, and galvanizing of metals. The characteristics of MFF include fever, chills, dizziness, nausea, fatigue, and joint pain (Ahsan et al. 2009). Based on the health profile of the city of Makassar in 2019 and 2020, the most common diseases experienced by the community were Upper Respiratory Tract Infections with 116,414 cases in 2020.

The study conducted in the Satando community aims to see the possible risks posed by the activity of manufacturing handmade goods made of copper, gold, and silver. In this study, it was known that 86.7% of respondents had Cu concentrations that had exceeded the normal average value of Cu concentrations in hair according to CTESA 2007 (Zhou et al. 2016).

In 2018, an environmental health risk analysis study was conducted in Malimongan with Cu and SO2 as the parameters studied. This study examined the concentration of Cu in the air at the respondents' houses. The results of the study showed that there was a risk due to exposure to Cu through inhalation (Mallongi et al. 2018). The current study conducted in the Satando community has the aim of directly knowing the concentration of Cu in the hair of the respondent acting as a biomaker for Cu poisoning. An assessment of risks due to exposure to Cu is made by calculating the intake which is then divided by the reference dose/RfC for Cu. The results showed that for real time calculations 2 respondents (6.7%) had RQ > 1 and 28 respondents had RQ < 1 or had no risk and all the results of the calculation of the THQ value had a value of less than one.

In Abidin's research (2015) it was found that the average value of Cu concentration in goldsmiths' hair (35.4 ug/g) was the highest data from studies ever conducted in Malaysia. This study also showed a clear association between Cu concentrations and occupational exposures (Abidin et al. 2015). This is in line with research conditions in the Satando community, in which the goldsmiths' activities cause exposure to Cu so that the Cu level found is above the average value of normal concentrations of Cu in human hair (Zhou et al. 2016). These results are in accordance with research which states that the rate of exposure affects the Cu concentration in respondents (Abidin et al. 2015; Jaccob 2008).

The indoor air quality inspection was conducted at the research location using the EPAM 5000. All of the workshops inspected are located in the same location or attached to the respondent's house. The inspection of the parameter PM10 in the room is made due to the ability of such agent to cause health problems related to breathing (Elbarbary et al. 2020; Khullar and Gupta 2017; Zhang et al. 2018). Health problems that arise can be caused by the body inhaling air containing pollutants. According to Salma (2002), the side effects of inhalation of aerosols will highly depend on the type of chemical, the duration of exposure and the exposure pathways. However, particle size is the most important factor that determines the location of the deposition and storage of the particle (Srithawirat et al., 2016).

The quality standard for the parameter PM10 is specified by PERMENKES Number 1077 of 2001 on Guidelines for Indoor Air Sanitation. According to Massey (2013), the exposure to PM10 mainly occurs indoors/at home. Based on the results of research on 30 respondents' workshops, it is found that only 1 location (out of 29 location points) exceeds the predetermined quality standard (141 ug/m3). Furthermore, the calculation of the RQ in goldsmith and non-goldsmith respondents shows that 100% have RQ < 1 in which the average real time values of RQ for the goldsmith and non-goldsmith groups are 0.16 and 004 while the average lifetime of RQ for the goldsmith and non-goldsmith groups are 0.18 and 006.

Research related to the effect of PM10 shows the presence of elements contained in PM10 particles (Zhang et al. 2018). Research conducted in China shows an increase of 2.5 times higher than the standard specified by the NAAQS which would lead to an increased risk (Cheng et al. 2018). Research in the Satando community itself shows RQ < 1 and THQ < 1 or no risk. This condition is influenced by several important factors, including a decline in productivity or work during the pandemic. This decrease in productivity will affect the source of dust/particles released into the air due to work.

A comparison of RQ and THQ values due to exposure to Cu and PM10 in respondents based on the duration of exposure (Dt) shows that respondents who stay longer have a higher probability of RQ values than other respondents. The distribution of this value can be seen in charts 1 and 2. This shows that modification of activity patterns and the concentration of agents in respondents is one of the risk management methods that can be used to improve human health. From the results of the study, it is known that there are several health complaints experienced by the two groups of respondents. Nausea, dizziness, fatigue, insomnia, and loss of appetite are some of the complaints felt by respondents both in goldsmith and non-goldsmith groups.

Research on diseases that can be caused by exposure to Cu and/or particles containing Cu indicates that Cu can cause Tyrolean infantile cirrhosis in India (Uauy, Maass, and Araya 2008), cardiovascular disease, osteoporosis (Angelova et al. 2011) and is also one of the causes of Metal Fume Fever (MFF) (Ahsan et al. 2009).

Metal Fume Fever is one of the occupational diseases occurring due to exposure to metal compounds in workers. Some of the common features are chills, fever, fatigue, nausea and dizziness (Ahsan et al. 2009). This series of problems of health complaints are also found in the respondents in this study, but the correlation between the two is not examined specifically.

According to Araya et al. (2007), research on the effects of exposure to Cu was carried out in depth at the Institute of Nutrition and Food Technology in Chile. Common complaints that emerged from the study were nausea and dizziness in respondents and an increase in symptoms which was directly proportional to the increase in Cu concentration in the water they drank. The results of this study are used as a reference for the NOAEL of Cu in the safe drinking water.

In general, the risks that may arise due to exposure to Cu and Cu-containing particles can be identified by looking at the symptoms that arise, but specific research on the RfC of Cu has not been known and determined exactly. Copper has been studied extensively by various parties; IRIS has studied Copper since 1987 but the determination of the RfC to determine a safe reference dose for exposure to Cu is not yet known (Taylor et al. 2020). Further research on the correlation between disease and RQ and THQ due to exposure to Cu will increase knowledge about quality improvement and environmental control that can improve the level of human health.

Conclusion

Based on the results of the study conducted in the Satando community, it can be concluded that the concentration of Cu in hair of 86.7% has exceeded the average normal concentration of Cu in hair but the PM10 concentration of 96.7% is still below the quality standard specified by PERMENKES 1077 of 2001. From the results of the calculation of RQ of Cu, RQ < 1 (93.%) is obtained. This shows that the risk that occurs due to exposure to Cu in family members of the Satando community in Malimongan is very small and the calculation of THQ shows that all have THQ < 1 (100%). From the results of the calculation of RQ and THQ due to exposure to PM10 a value of less than 1 (100%) is obtained. One of the risk management methods to be applied to the parameter Cu is to decrease the concentration of Cu found in respondents by modifying the activity patterns of respondents in both groups so that there is a decrease in intake rates. Furthermore, in the parameter PM10, the right risk management method is to maintain the current conditions for RQ and THQ to remain at a condition of less than 1 or no risk.

References

Abidin, E. Z., Sarva M. P, Anita A. R, Siti N. A. A., and Sharifah N. S. I. (2015). "Heavy Metals (Pb and Cu) Assessments in Hair Samples of Goldsmiths in Kelantan, Malaysia." Asia Pacific Environmental and Occupational Health Journal 1(1):1–8.

Ahsan, S. A., Lackovic, M., Katner, A., & Palermo, C. (2009). Metal fume fever: a review of the literature and cases reported to the Louisiana Poison Control Center. J La state Med soc, 161(6), 348-51.

Angelova, M., Asenova, S., Nedkova, V., & Koleva-Kolarova, R. (2011). Copper in the human organism. Trakia Journal of Sciences, 9(1), 88-98.

Araya, M., Olivares, M., & Pizarro, F. (2007). Copper in human health. International Journal of Environment and Health, 1(4), 608-620.

Cheng, X., Huang, Y., Zhang, S. P., Ni, S. J., & Long, Z. J. (2018). Characteristics, sources, and health risk assessment of trace elements in PM10 at an urban site in Chengdu, Southwest China. Aerosol and Air Quality Research, 18(2), 357-370.

Diantoro, Y. (2010). Emas: investasi & pengolahannya: pengolahan emas skala home industry. PT Gramedia Pustaka Utama.

Elbarbary, M., Honda, T., Morgan, G., Guo, Y., Guo, Y., Kowal, P., & Negin, J. (2020). Ambient air pollution exposure association with anaemia prevalence and haemoglobin levels in Chinese older adults. International journal of environmental research and public health, 17(9), 3209.

Jaccob, A. A. (2020). Evaluation of Lead and Copper content in hair of workers from oil product distribution companies in Iraq. Brazilian Journal of Pharmaceutical Sciences, 56.

Kementrian Lingkungan Hidup. (2010). Peraturan Menteri Negara Lingkungan Hidup Nomor 12 Tahun 2010 Tentang Pelaksanaan Pengendalian Pencemaran Udara Di Daerah.

Khullar, M., & Gupta, P. (2017). An Assessment of Indoor Air Quality (IAQ) in Metal industries of Delhi. International Journal of Environment, Agriculture and Biotechnology, 2(1), 238702.

Mallongi, A. (2019). Dinamika Polutan Dan Risiko Kesehatan Lingkungan. pertama. Yogyakarta: Gosyen Publishing.

Mallongi, A., Bustan, M. N., & Juliana, N. (2018, June). Risks Assessment due to the Exposure of Copper and Nitrogen Dioxide in the Goldsmith in Malimongan Makassar. In Journal of Physics: Conference Series (Vol. 1028, No. 1, p. 012036). IOP Publishing.

Palar, H. (1994). Pencemaran dan toksikologi logam berat. Jakarta: PT. Rineka Cipta.

Rahman, A. (2007). Public Health Assessment: Model Kajian Prediktif Dampak Lingkungan dan Aplikasinya untuk Manajemen Risiko Kesehatan. Jakarta: Pusat Kajian Kesehatan Lingkungan dan Industri Universitas Indonesia.

Setiani, O., Raharjo, M., Hanani, Y., & Budiyono, B. (2002). Imobilisasi Tembaga (Cu) dan Netralisasi Aktivitas Ion Hidrogen (pH) pada Limbah Cair Industri Peleburan Emas Dengan Batu Gamping (Limestone). Jurnal Kesehatan Lingkungan Indonesia, 1(1), 25-29.

Soedarto. (2013). Lingkungan Dan Kesehatan (Environment And Health). Pertama. Jakarta: Penerbit Sagung Seto.

Soemirat. (2013). Analisis Risiko Kesehatan Lingkungan. Pertama. Yogyakarta: Gadjah Mada University Press.

Srithawirat, T., Latif, M. T., & Sulaiman, F. R. (2016). Indoor PM10 and its heavy metal composition at a roadside residential environment, Phitsanulok, Thailand. Atmósfera, 29(4), 311-322.

Suhelmi, R. (2018). “Tesis Hubungan Pajanan Merkuri Dengan Gangguan Neurologi Pada Pengrajin Emas Di Kota Makassar.” Universitas Hassanuddin.

Taylor, A. A., Tsuji, J. S., Garry, M. R., McArdle, M. E., Goodfellow, W. L., Adams, W. J., & Menzie, C. A. (2020). Critical review of exposure and effects: Implications for setting regulatory health criteria for ingested copper. Environmental management, 65(1), 131-159.

Uauy, R., Maass, A., & Araya, M. (2008). Estimating risk from copper excess in human populations. The American journal of clinical nutrition, 88(3), 867S-871S.

Zhang, J., Wu, L., Fang, X., Li, F., Yang, Z., Wang, T., ... & Wei, E. (2018). Elemental composition and health risk assessment of PM10 and PM2. 5 in the roadside microenvironment in Tianjin, China. Aerosol and Air Quality Research, 18(7), 1817-1827.

Zhou, T., Li, Z., Shi, W., Wu, L., & Christie, P. (2017). Copper and zinc concentrations in human hair and popular foodstuffs in China. Human and Ecological Risk Assessment: An International Journal, 23(1), 112-124.