The Indonesian Journal of Occupational Safety and Health
2023, 12 (1): 54-63
p ISSN: 2301 8046, e ISSN: 2540 7872
http://doi.org10.20473/ijosh.v12i1.2023.54-63

ORIGINAL ARTICLE

Risk Assessment of Photokeratitis Among the Welders of Gamelan Gongs in Ponorogo, Indonesia

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ABSTRACT

Introduction: Welding is one of the activities in the manufacture of gamelan gong which has the potential for causing photokeratitis in workers. Photokeratitis can occur as a result of acute exposure to UV rays in the eyes of workers. Risk assessment was used to determine the magnitude of the risk of several factors causing photokeratitis. The purpose of the study was to analyze the risk of photokeratitis among the welders of gamelan gongs in Ponorogo Regency based on the concept of epidemiology. **Methods:** The research design was cross sectional which was carried out during the Covid-19 pandemic in May 2021. The population of this study was welders making gamelan gongs in Ponorogo, Indonesia. There were six respondents. Data was collected by interviews, discussions, and observations. The variables, namely host, agent, and environment, were identified as risk factors, then risk analysis was carried out using the semi-quantitative technique by taking into account the level of frequency and severity. The risk evaluation was completed using the ALARP concept. **Results:** The causative factors of photokeratitis found the host category were age and working period which was considered moderate risk, and behavior using PPE which was considered high risk. In the agent category, the UV exposure intensity was considered high-risk. The environmental factors, namely working time, exposure distance, and welding location were considered moderate risk. **Conclusion:** The factors of photokeratitis still exist, thus continuous control efforts are needed.

Keywords: gamelan gong craftsmen, photokeratitis, risk assessment, welding

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INTRODUCTION

Welding is a technique of connecting two objects by boiling. As a filler, heat is needed to dilute the fuel to be connected from the welding wire. A strong, permanent connection is formed when heat becomes a fire, where metal fragments in the form of particles hold the metal together (Siswanto, 2018). Welding and cutting can be found in formal and informal industrial activities in Indonesia.

Informal sector workers are most vulnerable to various risks that cause work accidents and occupational diseases, even death (Rokom, 2016). A study conducted on informal sector welders showed that as many as 38 out of 155 welders suffered from work-related morbidity with the highest symptoms of watery eyes (67.1%) (Joseph *et al*., 2017).

Based on data from Statistics Indonesia (BPS), from 136.18 million workers, more than 74.08 million people work in the informal sector. Statistical data shows 58.22% of Indonesian workers currently work in the informal sector with low salaries, risky jobs, and no secure contracts, including social protection or worker representation (Indonesian Central Statistics Agency, 2018). Law No. 36 of 2009 Article 164 concerning occupational health states that occupational health efforts are aimed at protecting workers to live healthy and free from health problems and adverse effects caused by

Cite this as: Sari, R. K., *et al.* (2023) 'Risk Assessment of Photokeratitis Among the Welders of Gamelan Gongs in Ponorogo, Indonesia', *The Indonesian Journal of Occupational Safety and Health*, 12(1), pp. 54-63.

 doi:10.20473/ijosh.v12i1.2023.54-63
Received November 21, 2021; 1st revision December 09, 2021; 2nd revision January 27, 2022; Accepted February 04, 2022; Published: April 2023.
Published by Universitas Airlangga.

work. Occupational health efforts as referred to in Paragraph (1) cover workers in the formal and informal sectors (Law of the Republic of Indonesia, 2009). According to a study, more than half, namely 58.4%, of construction welding workshop workers experienced photokeratitis (Zahrah, 2018).

There are quite a lot of informal sector welding industries in Indonesia. This can be seen from the proportion of informal sector employment in Indonesia in 2018 was 44.13% (Indonesian Central Statistics Agency, 2018). Welders can be exposed to welding beam radiation during the welding process (Qolik *et al*., 2018). A study states that 20 of 32 workers subjectively admitted to having photokeratitis (Laila, 2017). The most common symptom was a sense of glare, where they felt like there was something blocking their view. Workers most at risk of having photokeratitis are generally those in contact with ultraviolet (UV) radiation sources, likewise in construction, manufacturing, mining, carpentry, auto repair, electrical work, plumbing, welding, and maintenance (American Optometric Association, 2021). In addition to being the most unprotected, there is a lack of information on occupational safety and health in informal groups, so that workers do not understand about preventing accidents and occupational diseases at work (Priyandi, 2017).

Welding sparks from the welding process can cause eye injury in 1,390 cases (5.1%), which are reported as photokeratitis (American Optometric Association, 2021). Eye injuries are the leading cause of preventable blindness worldwide (Willmann, Fu and Melanson, 2021). There are more than 20,000 cases of eye injuries every year in the workplace. These eye injuries vary from mild to severe, ranging from decreased vision to blindness (United States Department Of Labor, 2015). Riskesdas in 2018 stated that one of the causes of eye injuries is work accidents caused by sharp objects, blunt tools or machines, falling objects, poisoning, radiation, burns and so on (Health Research and Development Agency, 2018).

Research in welding activity showed that there were 88.5% respondents affected by photokeratitis syndrome, there were 38.5% respondents who were at risk according to age, 76.9% respondents according to years of service, 100% respondents are at risk according to length of exposure, 100% respondents are at risk according to the amount of ultraviolet radiation, 84.6% respondents are at risk according to welding distance (Nurgazali, 2016). Research found that the most common diseases associated with radiation were pterygium, photokeratitis (Wright and Norval, 2021).

Research showed that the amount of radiation affects the high level of photokeratitis symptoms felt by welding workers (Firmansah, 2015). Exposure to workers' eyes due to light or smoke from welding work can be related to the working period (Pratiwi, Widada and Yulis, 2015). Other studies have shown that tenure has a relationship with conjunctivitis (Harahap, Rachman and Simanjuntak, 2017). The longer a person works, the greater the danger of exposure to light and smoke to the eyes. This is reinforced by the results of a study which concluded that there was a relationship between the use of personal protective equipment and complaints of conjunctivitis in small industrial welding workers (Anastasia and Puspita, 2018).

Electromagnetic radiation disease caused by ultraviolet radiation is photokeratitis (Canadian Center for Occupational Health and Safety (CCOHS), 2016). Photokeratitis, also known as welder's flash or arc eye, is an acute inflammation of the corneal epithelium due to high exposure to ultraviolet light, both natural and artificial sources. Some of the symptoms that occur after 6 to 12 hours of exposure to ultraviolet light, namely eye pain, blurred vision, watery eyes, discomfort in the eyes, and excessive glare when looking at light/ photophobia. Within 24 to 48 hours, the cornea can repair itself without leaving a scar. If this happens continuously and is not treated then infection can occur, and will cause serious problems and even cause decreased vision.

Photokeratitis is the most common type of eye injury found mostly caused by welding activity (31.7%) (Yuda, 2019). Acute UV exposure causes photokeratitis and induces apoptosis in corneal cells (The College of Optometrists, 2021). Photokeratitis is an eye disease or acute effect of ultraviolet (UV) radiation, which causes pain (Moore *et al*., 2010). Ultraviolet radiation can cause symptoms of photokeratitis in the eye, such as gritty eyes, excessive tearing, photophobia, abnormal twitching, visual disturbances/blurring, eye pain, and eye irritation (Canadian Center for Occupational Health and Safety (CCOHS), 2018). In general, eye pain and decreased visual acuity occur about 6-12 hours after injury (The College of Optometrists, 2021). Long term (chronic) effects caused by prolonged UV radiation, for example an injury to the eye such as cataracts, carcimentation, pterygium while on the skin such as keratosis actinic, premature aging and skin cancer (Modenese *et al*., 2018).

Risk assessment is an attempt to calculate the magnitude of a risk and determine whether the risk is acceptable or not (Ramli, 2018). The results of the risk assessment research become the basis for risk control, so that it can reduce or eliminate the potential and risk of work accidents and occupational diseases in the company (Handoko and Rahardjo, 2017). Risk assessment can be used to determine the magnitude of the risk of several factors causing photokeratitis symptoms.

The epidemiological triangle (epidemiological triad) is a basic concept in epidemiology that describes three main factors that play a role in the occurrence of a disease or health problem, namely the host, agent (cause), and environment (Irwan, 2017). Factors causing symptoms of photokeratitis can be referred to in three components that cause disease, namely host, agent, environment, called the epidemiological triangle theory. The host factors are age, gender, race, ethnicity, body anatomy, and nutritional status. Agent (cause) is an element of nutrition, chemical, physical, biological, which causes the occurrence of a disease. The environment is an external factor from an individual belonging to the physical, environmental, and social environment that supports the occurrence of a disease (Irwan, 2017)

Industry in Ponorogo consists of 327 units of formal industry and 3503 units of informal industry, as well as the informal sector absorbing 81.61% of the workforce and the formal sector absorbing 18.39% of the workforce. (Ponorogo Central Statistics Agency, 2018). One of the informal sectors in Ponorogo is the manufacture of gamelan gongs. Gamelan gong craftsmen are one of the informal industries in Ponorogo, which have stages welding of work. The first stage of making gamelan gongs is cutting the iron plate using iron scissors according to the pattern. Next, the iron pattern is formed in a circle using a hammer. After the pattern is formed, it then goes through the welding process to unite all the patterns. Welding using carbide welding. After the gamelan is formed, then the "laras" is carried out which aims to obtain the desired sound. The last stage of the process of making gamelan gongs is painting. Painting using a compressor machine. All gamelan gong-making activities are carried out by sitting on a very short chair with the tools and production processes placed on the floor.

The work process of making gamelan gongs has various potential hazards that can cause health and safety problems for workers. The highest potential hazard in the gamelan gong industry is welding activity which can cause photokeratitis. The results of the interviews with welders and initial observations on welding in the process of making gamelan gongs in Ponorogo Regency showed that some workers admitted to experiencing symptoms of photokeratitis such as red eyes, burning eyes, and sore eyes. The results of the initial observations revealed that some workers did not use the appropriate personal protective equipment (PPE) to protect their eyes from harmful UV radiation when welding.

This study aimed to determine the risk categories of several factors causing photokeratitis seen through the epidemiological triangle occurred to the welders of gamelan gongs in Ponorogo Regency.

METHODS

This is a qualitative study. This is also an observational study and recorded phenomena in the given situation using a cross sectional design. The subjects in this study were welders making gamelan gongs in Ponorogo, Indonesia. There were six respondents for interviews and discussions (all welder of gamelan gongs, and business owner). The variables of this study are human (host), cause (agent), and environment. Data collection was in the form of primary data. Primary data were obtained from observations using the Hazard Identification, Risk Assessment (HIRA) observation sheet and interviews using interview guidelines. The host, agent, and environment are identified, then risk analysis was done using the semi-quantitative technique.

Research location on Gamelan Gong Industry Center in Ponorogo, Jawa Timur. This research was conducted during the Corona Virus Disease-2019 (COVID-19) pandemic, namely in May 2021. The ethical test of this research has been approved by the ethical commission of the Faculty of Dentistry, Universitas Airlangga, Surabaya with the number 269/HRECCFODM/V/2021.

Hazard Identification

Hazard factors that may occur while welding causing photokeratitis were identified. The identified hazard factors come from the host, agent, and environment. Identification of risk factors is carried out by interviewing workers, observing the work environment and workers while doing work and literature review. The results of the identification of hazard factors were collected using the Hazard Identification Risk Assessment (HIRA) worksheet.

Risk Analysis

Risk Analysis is a process to determine the amount of risk from the identified causative factors (variables). Risk analysis was carried out by taking into account the frequency and severity of the occurrence. Risk analysis of host, agent, and environment variables is carried out by determining the level of frequency and severity. Frequency is the frequency of occurrence of photokeratitis symptoms based on the findings of the causative factors that have been identified. Consequence is the severity experienced by workers if they actually experience photokeratitis symptoms originating from identified causative factors.

Risk (R) = Frequency (F) * Consequence (C)

F =(Frequency Score+Variable Score)/2

C =(Consequence Score+Variable Score)/2

The frequency and severity were recorded and then analyzed using a risk matrix table. The results of the analysis showed that the hazards are categorized as low, moderate, high, and extreme risks.

Table 1. Frequency Score

Value	Description
5	Almost Certain. Very likely to happen or almost certain to happen, very often.
4	Likely. It will most likely happen, but not a constant occurrence.
3	Possible. It can happen occasionally.
2	Remote Possible. Not expected to happen, but it's possible.
1	Conceivable. Very unlikely / difficult to happen, very unlikely will happen.

Source: (The University of Adelaide, 2016)

Frequency scores can be divided into 5 categories of values. a value of one indicates the lowest frequency value, and a value of 5 indicates the highest frequency value.

Variable scores are divided into five value categories. a value of one indicates the lowest variable value, and a value of 5 indicates the highest variable value.

Consequence scores are divided into 5 value categories. a value of one indicates the lowest consequence value, and a value of 5 indicates the highest consequence value.

Risk Evaluation

Risk evaluation shows the level of risks whether they are acceptable or not. The results of

Table 2. Variable Score

Value	Description
5	Extreme
4	Major
3	Moderate
2	Minor
1	Insignificant

Table 2. Consequence Score

Value	Description
5	Extreme. Causative factors or circumstances that have the potential to have a significant adverse impact or disaster/ destruction on the company.
4	Major. The causal factors or critical conditions that can be overcome with proper management.
3	Moderate. The causative factor or event or event is quite large but can be managed under normal circumstances.
2	Minor. A causal factor or event with consequences that can be immediately addressed but requires management efforts to minimize its impact.
1	Insignificant. With little loss, existing controls and procedures can already address the event or circumstance or causative factor.

Source: (The University of Adelaide, 2016) the risk analysis in the form of risk levels were evaluated using the criteria in the As Low As Reasonably Practicable (ALARP) concept on AS/NZS 4360. Based on the ALARP concept, risk can be categorized into three parts: unacceptable risk (intolerable region) having an extreme risk level must be controlled so that risk can fall into a lower category, tolerable risk (tolerable region) having high risk and medium risk only if future risk control cannot be implemented, and (acceptable region) all risks in the low category are acceptable risk has a low risk level.

Table 4. Risk Assessment Matrix

Frequency	Consequence (C)				
	5	4	3	2	1
5	25	20	15	10	5
4	20	16	12	8	4
3	15	12	9	6	3
2	10	8	6	4	2
1	5	4	3	2	1

Source: (The University of Adelaide, 2016)

Table 5. Risk Category

Risk Level	
Risk Classification	Explanation
20 – 25	Extreme Level
10 – 16	High Level
5 – 9	Medium Level
1 – 4	Low Level

Source: (The University of Adelaide, 2016)

RESULT

Risk assessment revealed that factors causing photokeratitis were identified in the host (age, behavior, and working period), agent (the intensity of UV light exposure), and environment (working time, exposure distance, and welding location). From the risk analysis, five factors were found to be in moderate risk category and two factors were in high-risk category. Based on ALARP category, variable showed into tolerable category. The results of identification of hazard sources, risk analysis, and risk categories based on ALARP in welding activities for making gamelan gongs can be seen in Table 6.

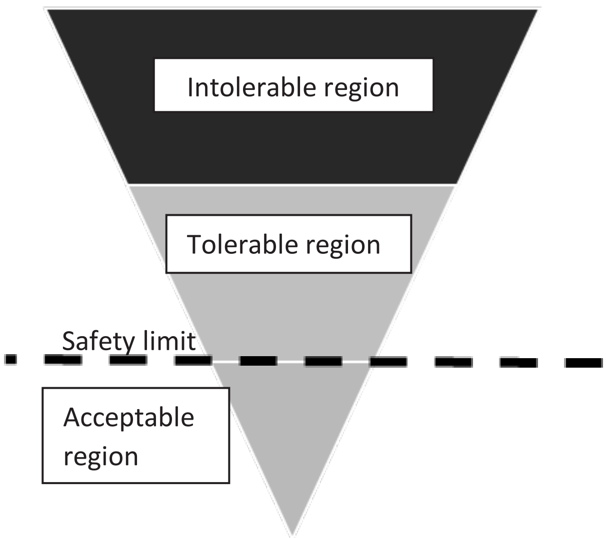

Figure 1. As Low as Reasonably Practicable (ALARP) Concept

Table 6. Results of Hazard Identification, Risk Analysis, ALARP Category in Welding Activities for Making Gamelan Gong

Variable	Source of Hazard (Causing Factor)	Hazard Category	Risk Analysis		Risk Rating	ALARP Category
			F	C		
Host	Worker Age	-	3	2.5	7.5 (Medium Risk)	-
	Worker Behavior	Unsafe Action	3.5	3	10.5 (High Risk)	tolerable region
	Working Period	Unsafe Action	3	2.5	7.5 (Medium Risk)	tolerable region
Agent	UV Light Intensity	Unsafe Condition	3.5	3	10.5 (High Risk)	tolerable region
Environment	Working Time	Unsafe Condition	3	2.5	7.5 (Medium Risk)	tolerable region
	Exposure Distance	Unsafe Condition	2.5	2	5 (Medium Risk)	tolerable region
	Welding Location	Unsafe Condition	2.5	2	5 (Medium Risk)	tolerable region

DISCUSSION

Welding for the manufacture of gamelan gongs is carried out by carbide welding (Oxy-Acetylene) which uses oxygen and acetylene gases. The use of oxygen and acetylene in welding produces a large amount of UV radiation and can expose welders' eyes (Nakashima *et al*., 2016).

The results of the interviews with workers showed that on average, they experienced symptoms of photokeratitis with a frequency of one or more in a month. The symptoms were usually handled with first aid (eye drops). Eye irritation may be caused by frequent exposure to ultraviolet light in welding (Government of South Australia, 2019). Symptoms of photokeratitis experienced by workers are caused by factors of worker age, worker behavior, working period, UV intensity, working time, exposure distance, and welding location. Several factors related to conjunctivitis (red eyes) in welders, including working period, working hours, and use of personal protective equipment (PPE) (Watson, Cabrera-Aguas and Khoo, 2018).

Worker Age

The optimal age of welders is at the range of 26-35 years old. Someone who is over 35 years old will experience a decrease in his physical organ functions, one of which is vision (Suma'mur, 2020).

The results of the data collection showed that the average worker had symptoms of photokeratitis at the age of 44-60 years with a moderate risk for photokeratitis. The age of the workers found that five workers were in the age of 44-60 years, and one worker was at the age of 70 years. Research mentions that workers aged ≥ 40 years are at risk of photokeratitis and risk increased per 10 years by age (Slagor, Cour and Bonde, 2016). In addition, it is known that increasing the age decreases the sensitivity and increases the fragility of the cornea caused by mechanical stimuli such as UV radiation (Modenese, Korpinen and Gobba, 2018). According to the result of risk analysis, worker age belongs to the medium risk that cause photokeratitis among the welders of gamelan gongs in Ponorogo, Indonesia.

Worker Behavior

The worker behavior in this study refers to the use of personal protective equipment by workers. Regulation of the Minister of Manpower of the Republic of Indonesia number 5 of 2018 concerning Occupational Safety and Health in the Work Environment in article 7 paragraph 8 states that the use of personal protective equipment is an attempt to use a tool that functions to isolate part or all of the body from sources of danger (Minister of Manpower Regulation, 2018). The use of personal protective equipment (PPE) can affect the occurrence of photokeratitis symptoms, especially in the protection of eye organs (Suma'mur, 2020)

It was found that none of the workers used PPE for eye or face protection. Most workers did not know that the perceived symptoms came from the welding light. However, some workers understood that the perceived symptoms originated from welding. Therefore, the behavior of workers in using PPE was included in the high risk category for photokeratitis. Exposure to ultraviolet (UV) rays in workers' eyes requires personal protective equipment to reduce the risk of photokeratitis (googles or standard eye protection) (Piernick, Jahnke and Watson, 2019). Exposure to UV radiation in the eyes can be reduced effective by using eye protection goggles (98%), welding masks (48%), face shields (27.22%) (Bah *et al*., 2021). Poor use of PPE is one of the factors that can affect the onset of photokeratitis symptoms (Obarhoro *et al*., 2020). If workers are aware of hazards in the workplace, personal precautions are expected to emerge. Personal action based on awareness is very important in reducing worker exposure (Izadi *et al*., 2018). According to the ALARP concept, worker behavior belongs to the tolerable risk category.

Working Period

Working period is the period of time a person works which is calculated from the time he starts working in an agency (Law of the Republic of Indonesia, 2020). Workers who experience symptoms of photokeratitis have an average working period of 11-20 years. Therefore, working period was included in the category of moderate risk for photokeratitis. Those whose working period was > 5 years experienced more photo-kerato-conjunctivitis symptoms compared to ≤ 5 years (Ramdan, Mursyidah and Jubaedah, 2017). The results of study showed that working period can affect the visual acuity of welders (Łatka *et al*., 2018).

The longer a person's working period in a welding workshop, the higher the risk of them experiencing symptoms of acute photokeratitis (Heydariana *et al*., 2017). The lens of the eye that is exposed to welding radiation for a long time will experience impaired lens transparency, irritating the eyes which is characterized by pain, itching, and dark vision (Modenese and Gobba, 2021). The worker factor is taken from the characteristics of the working period, the category of moderate risk of photokeratitis is obtained. According to the ALARP concept, working period belongs to the tolerable risk category.

UV Light Intensity (Exposure)

Regulation of the Minister of Manpower of the Republic of Indonesia Number 5 of 2018 article 13 paragraph 4 point e states that limiting exposure to ultra violet (Ultra Violet) sources through working time arrangements (Minister of Manpower Regulation, 2018). Exposure to UV rays for a long time and repeatedly during welding will increase the risk of photokeratitis. The longer the workers work in the welding area, the longer the exposure to UV rays. Repeated exposure to UV rays from welding can cause cumulative damage to the corneal epithelium. In other words, over time, the damage will be more severe, and the regeneration function of the cornea will decrease, thereby increasing the risk of photokeratitis (Zahrah, 2018). Previous research found that there was a relationship between duration of exposure and complaints of conjunctivitis with an exposure duration of 2 hours/day having a 3.289 times greater risk of experiencing complaints of conjunctivitis compared to workers with an exposure duration of < 2 hours/day (Suherni *et al*., 2021).

The agent variable related to the intensity of UV rays resulting from welding was known from the length of exposure received by the eyes of workers who were exposed to UV rays. It was found that the average length of exposure was four hours when accumulated in one working day. The identified intensity of UV rays based on the length of exposure was included in the high-risk category for photokeratitis. A study stated that there was a difference in the average length of exposure between respondents who were exposed for 41.1 minutes, 16.9 minutes, and 1 second (Kuo *et al*., 2019). Research stated that there was a difference in the average length of exposure between respondents who were exposed for 41.1 minutes, 16.9 minutes, and 1 second with the incidence of photokerato conjunctivitis, indicating that the risky duration of exposure was > 40 minutes, and the duration of exposure that was less risky, i.e. exposure 40 minutes (Yuda, 2019).

The length of exposure is one of the factors that exacerbates the occurrence of welding flash/ flash burn. Longer exposure to UV radiation further aggravates the occurrence of welding flash (Astin, Mulyadi and Suyanto, 2016). The severity of the effects of exposure to workers' eyes occurs when workers receive UV light exposure for eight hours every day (Canadian Center for Occupational Health and Safety (CCOHS), 2018). According to the ALARP concept, the agent, as one of the variables in this study, which only consists of UV radiation exposure, belongs to the tolerable risk category.

Working Time

The working time of the welders is in accordance with the Regulations of the Minister of Manpower and Transmigration of the Republic of Indonesia which is less than or equal to eight hours per day or 40 hours a week (Canadian Center for Occupational Health and Safety (CCOHS), 2018). The average working time of the welders was > 6-8 hours per day, unless there were a lot of orders, where they might work overtime. Therefore, working time as a risk factor in this study belongs in the moderate risk category for photokeratitis. The study found that the duration of exposure 2 hours/ day had a 3,289 times greater risk of experiencing complaints of conjunctivitis compared to workers with an exposure duration of < 2 hours/day (Suherni *et al*., 2021). Research shows there is a relationship between working time and the incidence of photokeratitis. It was found that a number of workers who work for more than eight hours a day and those working overtime to complete their work within a certain period of time were found to suffer from photokeratitis (Yustheresani *et al*., 2020). Working time is included in the tolerable risk category according to the ALARP concept.

Exposure Distance

Exposure distance referred to in this study is the distance between the eye of the welders and the source of radiation while working (Australian Government, 2016). Based on research that has been done, the incidence of photokeratitis in workers with welding distance ≤45 cm (88.9%) is more than >45cm (Yustheresani *et al*., 2020).

The closer the welding distance, the higher the risk of experiencing photokeratitis (Arsanjani, 2017). Close welding distances can be aggravating and pose a risk of visual impairment. This is because the spectrum of UV radiation will directly absorb the eye (Kurniawan, 2017).

The welding carried out by workers in Ponorogo had an average exposure distance of 60-52 cm, meaning that the exposure distance has a moderate risk category for photokeratitis. Research in Depok stated that there was a difference between the incidence of photo-kerato-conjunctivitis at a distance of less than 45 cm and more than 45 cm (Yustheresani *et al*., 2020). Welding distance is an important factor that affects the intensity of UV radiation to the eye (Yustheresani *et al*., 2020). Exposure distance is included in the tolerable risk category according to the ALARP concept.

Welding Location

The condition of the welding location means the existence of a roof and walls on both sides so as to allow workers to also get exposure to UV rays from the work environment. Thus, welding location belongs to the moderate risk category for photokeratitis. The location of the welding is related to the amount of direct sunlight that exposes the welder, the risk will be greater when exposed in the middle of the day (Tenkate, 2017). Reflecting Ultraviolet (UV) radiation sunlight from the ground and work surfaces and copper roofing plays an important role in increasing direct UV exposure (Ramdan, Mursyidah and Jubaedah, 2017). The ICNIRP concluded that outdoor workers receive significant exposure to UVR and thus increase the risk of consequences associated with overexposure to UVR in the eyes and skin (International Commission on Non-Ionizing Radiation Protection, 2020). Welding location is included in the tolerable risk category according to the ALARP concept.

CONCLUSION

Risk factors for photokeratitis still exist among the welders of gamelan gongs in Ponorogo, so continuous control efforts are needed. The use of PPE is required to reduce the risk of photokeratitis among the welders of gamelan gongs in Ponorogo. They are expected to use PPE, such as eye and face protection (googles and face sheets). for further research, the addition of research variables is better to find out more factors that cause photokeratitis, so that it is more precise in determining control.

ACKNOWLEDGMENTS

The author would like to thank the Master of Occupational Health and Safety Study Program, Faculty of Public Health, Universitas Airlangga so that the writing of this article could be completed.

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