

## ORIGINAL ARTICLE

# Occupational Hazards, the Use of Ppe, and Health Impacts Among Welders in Sumedang, West Java, Indonesia

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## ABSTRACT

**Introduction:** Welding is indirectly related to occupational hazards that may cause work-related diseases and trauma to the welders. The present study is aimed to analyze the occupational health hazards, PPE, health impact and also to determine the relationship between the use of Personal Protective Equipments (PPE) and acute health effects.

**Methods:** This was a cross-sectional study and data was collected via questionnaire and observation. **Results:** The most hazardous effect mentioned by welders was the bright light (64.6%), the main PPE awareness was safety glasses (61.4%) and the most impact awareness was on burns (45.7%). When discussed about PPE; safety glasses was used by all (100%) but there were other hazards like no hearing protection (81.9%), using ordinary shoes (54.3%) using slippers (23.6%) and 85% were using normal clothes during duty. The use of PPE has a relationship with the prevention of acute health effects. **Conclusion:** many welders were aware of welding hazards and PPE but many did not use the PPE during welding as a protection against the hazards. Hence, the local government needs to coordinate across related departments to identify the incidents and diseases resulting from welding which will then enhance monitoring and enable them to provide regular hazard prevention education. It is indeed necessary to conduct further research on the factors that prevent welders from using PPE properly and correctly.

**Keywords:** Welding, Occupational, Hazard, PPE, Health impact

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## INTRODUCTION

An occupational health hazard will arise if someone is in contact with something that can cause impairment/damage to the body when there is excessive exposure. Occupational health hazards can cause illness instigated by exposure to a source of hazard at the workplace. Welding has a potential occupational hazard to welder's health. Welding is a work that involves lot of heat generation that can cause explosions, fires, adverse health impacts, and even death (1).

Work-related exposures to substances, dust, and fumes in numerous configurations comprises of around 4,000 fatalities a year, and around 38,000 people are diagnosed with lung or breathing problems conceivably instigated

by their work (2). Moreover work-related hazards might cause work-related diseases and traumas.

Chemical, biological, physical, ergonomic, and psychological factors are potential occupational health hazards that are common in the workplace(3) which imposes short-term potential occupational health and safety hazards such as fire, electrical hazards, mechanical hazards, and poor housekeeping. Noxious substances emitted from welding sticks put welders at an extra work environment risk that maybe less urgent but no less life-threatening conditions of lungs, brain, and nerve injuries, such as Manganism (Welders' Parkinson's disease) (4).

It was discovered in a previous study that the welders utilising PPE were those who were aware of hazards. But still there was a gap that between the welder though aware of the hazard but did not understand the importance of PPE (90%).The use of PPE was still not implemented in the workplace (47%)(5). Welders do not

utilize PPE to defend themselves from welding activities; this can be reasoned by a low grade of cognizance (6).

This study is aimed to determine awareness of occupational health hazards, PPE, and health impacts, to determine the type of PPE used by welders during working hours and, to determine the relationship between the use of PPE and the acute health impacts.

According to Maertz(2017) (7), welding can be classified into two types: fusion (heat only) or pressure (heat and pressure) for joining two pieces of metal together. Electric arc welding, which includes Flux Core Arc Welding (FCAW), Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding/Metal Inert Gas (GMAW/MIG), and Gas Tungsten Arc Welding / Tungsten Inert Gas (GTAW/TIG), is divided into three categories by OSHA. Gas welding uses a flame from smouldering a gas (usually acetylene) to liquefy the pedestal metal at the joint to be bonded. Termite welding utilizes a substance effect to create a very high temperature rather than using gas fuel or electric current.

Welding air-borne metals/dust, fumes, and gases if swallowed or inhaled in can cause many health-related issues(7). Welders who were with gas metal arc welding had a pervasiveness of lungs disorders in comparison with those welders engaged in flux-cored arc welding (1). Welding activities have the utmost risk in terms of contact with huge strengths of nano particles (8).

The welding arc releases ultraviolet (UV) and infrared rays with a wavelength less than 0.4  $\mu\text{m}$  and greater than 0.7  $\mu\text{m}$  respectively. UV ray radiation can harm both skin and eyes. Even an inadvertent exposure to UV radiance from an arc can result in a condition known as arc eye. Welding can trigger blasts in the work place having igneous liquids, gases, dust, or vapours. Sparks, electric arcs, spatter, slag and hot metal are sources of ignition and blast if preventive measures are not obeyed (9).

Electric shock is one of the utmost life-threatening and direct risks confronting a welder. Shock is generated when arc-welders pat two metals that have an electrical power between, typically 20-100 volts, thus turning out to be a portion of the path to ground (7).

Welding activities typically create noise levels of more than 85 decibels-A (dBA). Furthermore, welding is characteristically performed in locations where it is not uncommon for ambient noise to count to the decibel level. Welding engages the usage of large amount of gases under great pressure present in cylinders. The cylinders can be a combustion hazard if not kept correctly. Cylinders can also be a physical hazard if not fixed appropriately to avert valve obliteration and causing volatile discharge of the gas making a lethal missile(7).

In this study, the author will further discuss Personal protective equipment (PPE) that is utilized by welders and other welding shop workers. PPE abets to keep welders free from work-related accidents(10). Almost all welders have under gone work environment related incidents and traumas. The lesser use of PPE and the congruently high occurrence of incidents and traumas are common (11).

Welding personal protective equipment (PPE) consists of safety glasses, dust masks, goggles, face shields, respirators, gloves, safety shoes, and helmets. These are usually very useful when used and is well suited in foiling the contact or effect, protecting numerous body parts from radiation, hazardous substances, biological agents, hot particles, and foreign bodies (12).According to the American Welding Society (AWS) (2014), the utilization of PPE is a good safe practice and may be needed by governing bureaus (13). When engineering and administrative measures are neither feasible nor relevant, OSHA requires the use of personal protective equipment (PPE).

Welders are vulnerable to an extensive variety of breathing diseases (14). The recent research articulated that work-related exposure to welding fumes can substantially affect the pulmonary capacity. Smoking has a synergistic consequence when combined with welding fume exposure on pulmonary decline (15). Metal fume fever is usually a harmless and self-limiting syndrome that goes away after 12–48 hours of stopping the exposure, but it can be deadly, specifically for individuals with heart and lung diseases (16).

An occupational eye injury study was conducted in Bahrain, mentioned that the most frequently injured were construction workers, followed by welders (17). Radiation in the visible and near-infrared spectrum (400-1400 nm) enters the eye and is absorbed by the retina, where it causes thermal or photochemical damage that, if the intensity and duration are high enough, can be permanent and sight-threatening(9). The majority of welders have experienced eye-related symptoms (18). Welders experienced work-related diseases, with the upper body, particularly the upper arms, being the most commonly damaged body part. The most prevalent type of harm suffered by welders was burns(19).

## **MATERIALS AND METHODS**

This research was a quantitative study with the study group consisting of workers who were exposed to welding hazards. The research site was at Sumedang Regency, West Java, Indonesia. The research method is a cross-sectional study, using questionnaires and observation. The researcher used quota sampling, as the welding workshops are generally located on the main road.

Slovin's formula was used to determine sample size, and 110 respondents participated in the study.

$$n = \frac{N}{(1 + Ne^2)}$$

Slovin's formula(20)

To anticipate respondents dropping out, it is necessary to make corrections with the following calculation:

$$N = n/(1-f)$$

$$N = 110 / (1-10\%)$$

N = 122.22 or 122. The sample size ranges from 110 to 122 (acceptable range) in case some respondents drop out from this research.

The Z'Gambo's welding and awareness questionnaires was tested among 30 welders from the sub-district Sumedang Selatan, Sumedang Utara, and Tanjungsari with C- $\alpha$  0.974 for the welding questionnaires and C- $\alpha$  0.763 for the awareness questionnaires. The scoring of awareness level was based on the mean score of occupational health, welding PPE, and health impact awareness. Above the mean score is categorized as good awareness and below the mean score is poor awareness.

### Ethical Clearance

This study was approved by Pemerintah Daerah Kabupaten Sumedang, Indonesia Nomor: 503/KEP. FD0687E5-PTSP/2020, 12th September 2020.

## RESULTS

Welders realized that bright light is a common hazard in welding workshops. The mean score of occupational hazard awareness is 50.7 with a standard deviation ( $\sigma$ ) at 14.52, above the mean score is good and below the mean score is poor. There were 80 welders who were able to mention this hazard during welding, followed by welding fumes/gas that was mentioned by 64 welders, while flying sparks and particles were mentioned by 56 welders. Among all occupational hazards, vibration and uncomfortable work posture were the least mentioned by welding workers, 32 and 33 people, respectively, meaning that there were still many welding workers who were not aware of these two hazards.

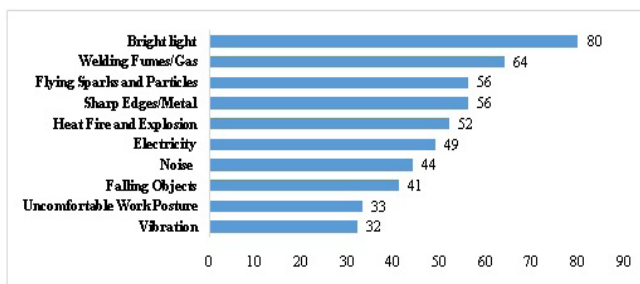


Figure 1. Occupational Hazards Awareness

The mean score of PPE awareness is 56.38 with a standard deviation ( $\sigma$ ) of 14.01, above the mean score is good and below the mean score is poor. With regards to the PPE awareness, there were 78 welders who showed good awareness in the use of safety glasses, followed by safety shoes mentioned by 68 welders and safety gloves by 67 welders. Meanwhile, the least mentioned PPE by welders was the welding helmet. The majority of welders (71.6%) were not aware that the welding helmet is also a part of the PPE that must be used during welding.

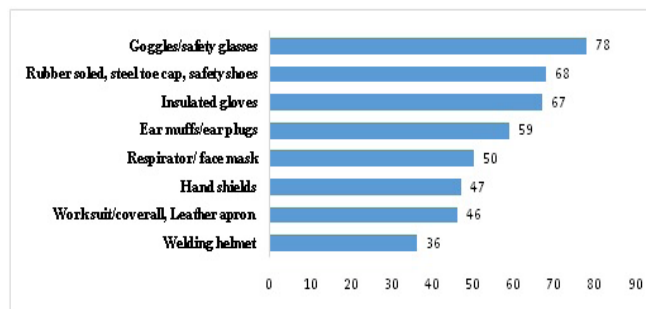


Figure 2. Personal protective equipment awareness

The mean score of health impact awareness is 53.10 with a standard deviation ( $\sigma$ ) of 3.41, above the mean score is good and below the mean score is poor. Almost all welding workers had good awareness of health impacts where they were able to mention that burns were common health impact for welders, it was mentioned by 58 people, conjunctivitis was mentioned by 56 welders and irritation of the eyes, nose, chest and the airway was mentioned by 55 welders.

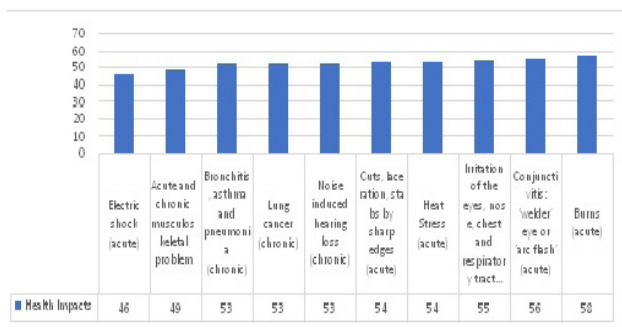


Figure 3. Health impact awareness

While the least health impact mentioned by welding workers was regarding electric shock, (46 welders). The welders were less aware of electric shock as a health impact caused by the peeled cables from electrical equipment such as welding, grinding, and cutting machines touched with bare hands.

Based on the observation results during welding activities in the welding workshop, it was found in 44 welding workshops, the hazards of airborne dust/fumes/gases and noise were clearly sighted. Other welding hazards such as the sharp and rough edges were found in 41 workshops, flying particles in 37 welding workshops, and intense light in 36 welding workshops. Among the hazards described in Figure 3 that were least

encountered at the time of observation were the use of solvents and falling objects in 9 welding workshops.

Almost, all welding workshops did not use complete and adequate personal protective equipment during welding activities. Generally PPE was only worn, but safety glasses and face shields were not worn by welding workers, in case of government institution or projects that required the use of PPE. All welding workshops did not have adequate PPE storage areas, welders stored or hung PPE together with tools that were not protected from dust.

The relationship between the use of eye and face PPE and acute health effects is described in the table below. Correlate bivariate was used to analyze this relationship.

**Table I. Awareness level proportion among welders (n=127)**

|                               | Acute Health Effects |  |                           |
|-------------------------------|----------------------|--|---------------------------|
|                               | Sig. (2 tailed)      | Analysis   | Symptoms or effects       |
| Use of eye & face PPE         | 0.000                | < 0.05<br>(there is significant relationship)    | Eye symptoms              |
| Use of respiratory protection | 0.042                | < 0.05<br>(there is significant relationship)    | Respiratory symptoms      |
| Use of respiratory protection | 0.017                | < 0.05<br>(there is significant relationship)    | Nasal symptoms            |
| Use of feet protection        | 0.005                | < 0.05<br>(there is significant relationship)    | Burns                     |
| Use of respiratory protection | 0.024                | < 0.05<br>(there is significant relationship)    | Metal fume fever symptoms |
| Use of hand protection        | 0.354                | > 0.05<br>(there is no significant relationship) | Cut wound                 |
| Use of body protection        | 0.614                | > 0.05<br>(there is no significant relationship) | Burns                     |

The above analysis is based on the hypothesis that there is a significant difference between the use of PPE and the occurrence of acute health impacts. Based on the analysis, the use of PPE for the eyes, respiratory system, and feet have been associated with the reduction of acute health effect,  $H_0$  is rejected and  $H_1$  is accepted.

However, the use of PPE has no relationship with the incidence of cut wounds. This could have been caused by other factors or due to other activities that were not

directly related to welding activities or the location of the cut itself. Likewise, the PPE on the body has no relationship with the burns as burn maybe in different areas that was not protected by the body PPE. Based on the seven data above, in general, the hypothesis that is accepted is that there is difference between the use of PPE and the occurrence of acute health impacts.

## DISCUSSION

There were six types of PPE welding attained in this study including eye and face protection consisting of safety glasses, welding shields, and a welding helmet. Hearing protection device consisting of earmuffs and earplugs. Respiratory protection device consisted of face mask and respirator, then feet protection device consisting of safety shoes. Ordinary shoes and slippers were not recommended for welding PPE as they could not protect the welders from fire hazards that caused burns. Hand protection consists of insulated gloves. Ordinary gloves were not recommended to use when welding. The last one was a body protection device consisting of a work suit/coverall and a leather apron, while ordinary clothes were not recommended to be used because they could not protect the body from sparks, but these clothes had to be protected with a coverall or leather apron. This data is consistent with a study conducted by Wanjiku (2017) and Ahmad et al. (2019),(12,21)that reported all welding PPE mentioned by welders used additional PPE namely knee joints mats. In general, the description of the welders from the results of this study showed that many of them only wore safety glasses, did not wear hearing protection, only wore cloth masks, wore ordinary shoes, did not wear hand protection, and only wore ordinary clothes.

Based on statistical data, there were two groups of welders who were at risk of getting health impacts namely group welders who never used PPE at all and who used PPE occasionally. These two groups had given a significant number of health impacts experienced by welders. It is consistent with a study conducted by Joshi, Dhakal& Shrestha (2021) (22).They reported that welders who do not use PPE experienced different types of health problems.

The purchase of PPE by welding workshop owners had focused more on procuring eyes and face protection, while the other PPE was still not available properly yet. They purchase eyes and face PPE as these are deemed very important. In addition, the PPE prices for eyes and face are not too expensive compared to other PPE and are widely available at PPE stores. Other PPE was quite expensive in the market so the owner of a welding workshop was constrained by capital. A similar finding was found by researchers Joshi, Dhakal& Shrestha (2021) (22) who reported that safety goggles are used by 90.6% of welders and this type of PPE is available in all metal workshops. However, the researchers did not give

the reason of eye protection use in all metal workshops. In another study conducted by Obarhoro et al. (2020) safety goggles (57.7%) was used by welders is perceived to prevent eye injury and so many welders use it (23). This study also confirmed that the common problem at the welding workshop is inadequate PPE but it did not explain the reason for this finding.

Based on the results of observations in all welding workshops, some hazards were found like the placement of welding materials that were not neatly arranged. The gas cylinder appeared to be standing unsecured. If the gas cylinder fell down and hit on people, it would cause injury or the cylinder head would come off so that the high-pressure gas in the tube could push the tube, as a result, it could damage the building and injure the people around the welding workshop. It is in line with the study that was conducted by Onguto(2020), who mentioned that only few workshops (13%) had secured gas cylinders (23).

In this study, it was found that solid calcium carbide was used as a material for a homemade acetylene gas which could be dangerous if there was a back-flame from the torch into the acetylene hose; the flammable acetylene gas might explode the cylinder. This acetylene gas is used as welding fuel by welders (24).

In general, informal welding workshops did not have any tool certification issued by a standard organization. So the compatibility of the welding tools was uncertain including the cylinder used to collect and store acetylene gas. They only made a visual inspection of the tools and if it is damaged or worn out, then the tool was replaced. They did not have a standard operating procedure that was used as a basis for decision making.

Many welders had a basic awareness of the welding hazards; they were aware of at least one hazard. It was confirmed by the previous studies conducted by Budhatoki et al. (2014), and Hassan et al. (2017), that the welders realized that bright light, welding fumes, and flying sparks and particles were occupational hazards that were directly related to welding activities (5,6). Some other occupational hazards that were mentioned by welders were hazards such as sharp edges/metal, heat fire, and explosion, electricity, noise, falling objects, uncomfortable work posture, and vibration. The welding method that was most widely used in this study was the manual metal arc welding (MMAW) method, that metal arc welding is mostly used in small industries as the welding machine is a portable electrical device that can be utilized both inside and outside the workshop, especially in developing countries like Indonesia. The use of the MMA method is more practical and easier to use than other types.

This study result showed that the use of materials from stainless steel was currently widely utilized in welding

workshops to produce welding products such as fences and handrails (24). Stainless steel welding can give off dangerous welding fumes as they contain hexavalent-chromium and nickel, which can cause cancer even in small amounts (25,26).

Likewise, a face mask made of cloth was still not adequate to protect the respiratory tract from exposure to welding fumes. The cloth mask was also not used all the time as the welders felt stuffy, sometimes forgetting and the cloth mask was not clean. This corresponds with a study that was conducted in Saudi that welding shields and safety glasses were reported mostly used by welders (21).

When looking at awareness of PPE usage, there were quite a lot of welders who realized that safety glasses and safety gloves were the welding PPE that must definitely be used when working. They mentioned safety shoes, insulated gloves, earmuffs/earplugs, respirator/face masks, hand shields, coveralls, leather apron, and welding helmets. The same was mentioned in a study that was conducted by Budhathoki et al. (2014) reported that welders were aware of various welding PPE (5).

In this study, welders had awareness of the welding health impacts including burns, conjunctivitis, and irritation of the eyes, nose, and respiratory problems, which were widely mentioned by welders. There are other welding health impacts including heat stress, cuts, noise, lung cancer, bronchitis-asthma-pneumonia, musculoskeletal problems, and electric shock. The workers were aware of these health hazards, but they were not aware that many welding hazards will have an impact over a long period of time. These findings are in line with a study conducted by Onguto (2020) (27) that described self-reported health effects such as burns, cuts, general body weakness, body chills, eye problems, nasal symptoms, sneezing, and blocked nose.

The use of PPE has a relationship with acute health effects, meaning that if PPE is used correctly and properly, it can prevent health effects from occurring, but on the other hand, if it is not used correctly, it can cause illnesses. It is coherent with Budhatoki et al. (2014), wherein their study, it was concluded that the use of PPE at work and occupational hazards showed a significant relationship (5).

The use of eyes and face protection has a relationship with the health effect on the eye, meaning that welders who did not use safety glasses and welding shields all the time, complained of eye symptoms. Likewise, the use of PPE for respiration, due to improper use, complained of nasal and respiratory symptoms as well as metal fume fever symptoms. Burns on the feet and hands were often described by welders due to the fact that feet and hand PPE was not routinely used and some never used them at all.



## CONCLUSION

Several hazards had been identified in some welding workshops such as unsafe gas cylinders and poorly organized workplaces. The use of homemade acetylene gas had a risk of back flame and could cause a cylinder explosion. Bright light, welding fumes, and flying sparks and particles were well-known hazards among welders. Welders were aware of welding PPE, but many did not use them. The welding health impacts were widely mentioned by welders such as burns, conjunctivitis, and irritation of the eyes, nose, and airways.

The use of PPE had a relationship with acute health effects, if the welders used the PPE correctly and properly, it could protect them from acute health effects. However, this study had shown acute health effects both among welders who used the PPE sometimes or did not use them at all. The cough symptom was mostly expressed by welders in this study followed by sneezing, stuffy nose, and runny nose that was closely related to exposure to welding fume and dust in the upper airway.

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## REFERENCES

- Mehrifar Y, Zamanian Z, Pirami H. Respiratory exposure to toxic gases and metal fumes produced by welding processes and pulmonary function tests. *The international journal of occupational and environmental medicine*. 2019 Jan;10(1):40. doi:10.15171/ijjem.2019.1540
- Ferrett E. *Health and Safety in Construction Revision Guide: For the NEBOSH National Certificate in Construction Health and Safety*. Routledge; 2015 Sep 16.
- WSHC. *Workplace Safety and Health Guidelines; Workplace Housekeeping*. Singapore: Works Safety and Health Council. 2016
- ISHN. *Welding injuries in the workplace: Arc Eye, Burns, and Manganism (Welders' Parkinson's Disease)*. 2016 April 13. Available at: <https://www.ishn.com/articles/103738-welding-injuries-in-the-workplace>
- Budhathoki SS, Singh SB, Sagtani RA, Niraula SR, Pokharel PK. Awareness of occupational hazards and use of safety measures among welders: a cross-sectional study from eastern Nepal. *BMJ open*. 2014 May 1;4(6):e004646. doi:10.1136/bmjopen-2013-004646
- Hassan SM, Nasir U, Anwar K, Talib U. An assessment of the level of awareness and reported complaints regarding occupational health hazards and the utilization of personal protective equipments among the welders of Lahore, Pakistan. *International journal of occupational and environmental health*. 2017 Apr 3;23(2):98-109. doi.org/10.1080/10773525.2018.1426259
- Maertz, W. J. Follow the hazards control hierarchy to reduce welding risks. 2017 December 17. Available at: <https://www.ishn.com/articles/107699-follow-the-hazards-control-hierarchy-to-reduce-welding-risks>
- Arezes PM, Baptista JS, Barroso MP, Carneiro P, Cordeiro P, Costa N, Melo RB, Miguel AS, Perestrelo G, editors. *Occupational Safety and Hygiene VI: Book chapters from the 6th International Symposium on Occupation Safety and Hygiene (SHO 2018)*, March 26-27, 2018, Guimarras, Portugal. CRC Press; 2018 Mar 14.
- Mgonja CT. The effects of arc welding hazards to welders and people surrounding the welding area. *International Journal of Mechanical Engineering and Technology*. 2017;8(3):433-41.
- Hemmati, A., Rostami, A., &Farhangian, S. Safety Requirement for Welding Job at Confined Space. 1st International Conference on Oil, Gas, Petrochemical and HSE. Bushehr: Islamic Azad University of Bushehr, Iran.2017;1-5
- Awosan KJ, Makusidi MA, Ibrahim MT, Suleiman A, Magaji TG, Mbatifuh FG. Knowledge and safety practices related to exposure to physical and chemical hazards among welders in Sokoto, Nigeria. *Asian Journal of Medicine and Health*. 2017 Dec 20;9(1):1-1. doi:10.9734/AJMAH/2017/38572
- Wanjiku MF. *Factors Influencing Use Of Personal Protective Equipment By Motor Vehicle Repair Workers In Kigandaini, Thika*. Nairobi University. 2017.
- Safety and Health Fact Sheet No.33 Personal Protective Equipment (PPE) for Welding and Cutting. 2014 April. Available at: [https://app.aws.org/technical/facts/FACT-33\\_2014.pdf](https://app.aws.org/technical/facts/FACT-33_2014.pdf)
- Marongiu A, Hasan O, Ali A, Bakhsh S, George B, Irfan N, Minelli C, Canova C, Schofield S, De Matteis S, Cullinan P. Are welders more at risk of respiratory infections? Findings from a cross-sectional survey and analysis of medical records in shipyard workers: the WELSHIP project. *Thorax*. 2016 Jul;71(7):601-6. doi: 10.1136/thoraxjnl-2015-207912. Epub 2016 Mar 30. PMID: 27030577.
- Ghani N, Tariq F, Hassan S. Respiratory and physical ailments correlated with occupational exposure among welders in Pakistan. *J Pak Med Assoc*. 2017 Dec 1;67:1910-3.
- Roach LL. The relationship of welding fume exposure, smoking, and pulmonary function in welders. *Workplace health & safety*. 2018 Jan;66(1):34-40.

17. Almoosa A, Asal A, Atif M, Ayachit S, DOMS PH. Occupational Eye Injury: The Neglected Role of Eye Protection. *Bahrain Medical Bulletin*. 2017 Jun 1;39(2):82-4
18. Chauhan A, Anand T, Kishore J, Danielsen TE, Ingle GK. Occupational hazard exposure and general health profile of welders in rural Delhi. *Indian journal of occupational and environmental medicine*. 2014 Jan;18(1):21.
19. Ghimire A, Budhathoki SS, Niraula SR, Shrestha A, Pokharel PK. Work-related injury among welders working in metal workshops of dharan municipality, Nepal. *Journal of Nepal Health Research Council*. 2018 Jul 5;16(2):156-9. doi:http://dx.doi.org/10.3126/
20. Ellen S. Slovin's formula sampling techniques.2012
21. Balkhyour MA, Ahmad I, Rehan M. Assessment of personal protective equipment use and occupational exposures in small industries in Jeddah: Health implications for workers. *Saudi journal of biological sciences*. 2019 May 1;26(4):653-9. doi:10.1016/j.sjbs.2018.06.011
22. Joshi M, Dhakal G, Shrestha S. Occupational Health Problems, Workplace Environment and Utilization of Personal Protective Equipment among Welders of Banepa Municipality. *International Journal of Occupational Safety and Health*. 2020 Jul 20;10(2):100-7. doi:10.3126/ijosh.v10i2.30175
23. Obarhoro OI, Nwufu CR, Nworu B, Ibe SN, Iwuala CC, Ede A, Ebirim CI, Iwuoha G, Azuamah YC. Compliance in the Use of Personal Protective Equipment by Welders in Delta State, Nigeria. *International Journal of Research and Review*. 2020;7(1):21-6.
24. Filipek W, Broda K. Research on the concept of using calcium carbide as a source of energy for transport from the seabed. *New Trends in Production Engineering*. 2018;1:277-84. doi:10.2478/ntpe-2018-0034
25. Keane M, Siert A, Stone S, Chen BT. Profiling stainless steel welding processes to reduce fume emissions, hexavalent chromium emissions and operating costs in the workplace. *Journal of occupational and environmental hygiene*. 2016 Jan 2;13(1):1-8. doi:10.1080/15459624.2015.1072634
26. Proctor DM, Suh M, Campleman SL, Thompson CM. Assessment of the mode of action for hexavalent chromium-induced lung cancer following inhalation exposures. *Toxicology*. 2014 Nov 5;325:160-79. doi:10.1016/j.tox.2014.08.009
27. Onguto NO. Physical Hazards And Reported Health Effects Among Welders In The Small And Medium Enterprise Sector In Embakasi, Nairobi City County, Kenya (Doctoral Dissertation, Kenyatta University).2020.