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Studies on Shielded Metal Arc Welding Environment, Gaseous Emissions During Welding and Its Effect on the Health of Welders

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Abstract:- In recent years, there has been a greater emphasis on the health and safety of construction workers and others who operate in hazardous situations. Due to the current conditions and severe environmental restrictions enforced by the government, efforts are being made to improve the safety of labourers and skilled workers handling dangerous machinery and equipment. This manuscript attempts to examine the current environmental and safety conditions available in fabrication industries (particularly shielded metal arc welding). The current working circumstances have been studied. The health difficulties that welders encounter as a result of extended exposure to welding fumes, as well as the safety issues that welders face today, were analyzed by conducting a survey in different sites and ranking them using the vikor algorithm. Using this analysis, the important indicators influencing worker health and safety were identified.

Keywords*: safety, shielded metal arc welding fumes, gaseous emissions, environmental conditions, key factors.*

1. Introduction

Welding causes environmental pollution by emitting hazardous gases, particulate particles, and poisonous vapors [1]. These pollutants can degrade air quality, increase greenhouse gas emissions, and endanger the health of humans and wildlife. Proper control methods and environmentally friendly welding techniques are required to offset the negative effects on the environment [2]. The WHO provided recommendations to assist countries in combating air pollution and its negative impacts on health and the environment. It emphasized creating air quality standards, monitoring pollution levels, and implementing emission-reduction methods [3].

WHO's guidelines were to promote cleaner air and protect populations from pollution-related health risks [4]. Welding is an important procedure in many sectors, but it has various hazards that might endanger workers' health and safety. These risks include exposure to toxic vapours, extreme heat, and the possibility of fire or explosion [5]. Proper safety precautions, equipment, and training are essential for mitigating these risks and providing a safe working environment for welders [6]. Welding fumes are a major environmental problem because they contain harmful metals and chemicals that can impair air quality. These contaminants, when discharged into the atmosphere, have negative consequences on both the ecosystem and public health [7].

Controlling welding emissions through suitable ventilation and protective measures is critical for reducing their environmental impact [8]. Shielded Metal Arc Welding (SMAW) generates vapours including dangerous chemicals like metal oxides, gases, and particle debris [9]. Prolonged exposure to these chemicals can cause respiratory problems, brain impairment, and other major health risks in welders [10]. Implementing appropriate ventilation and utilising personal protective equipment are critical in reducing the hazards of SMAW vapours in

the workplace [11]. Welders operating with Shielded Metal Arc Welding (SMAW) equipment must prioritise safety due to the risks of being exposed to high temperatures, intense UV radiation, and hazardous gases [12].

To avoid burns, eye injuries, and breathing problems, wear proper protective gear such as welding helmets, gloves, and respiratory protection. Furthermore, keeping a well-ventilated workspace and adhering to established safety measures are crucial to establishing a safe working environment for SMAW operators [13]. Welders who are exposed to harmful fumes from shielded metal arc welding (SMAW) equipment face substantial health hazards, including respiratory disorders such asthma, bronchitis, and chronic obstructive pulmonary disease (COPD) [14]. Prolonged inhalation of welding fumes can cause neurological issues, renal damage, and even lung cancer due to the presence of toxic metals such as manganese and chromium. To mitigate these harmful health effects, welders must be protected with sufficient ventilation, respiratory protection, and regular health monitoring [15].

Welder safety is critical because of the lengthy exposure to harmful surroundings associated with the job, particularly while working with hazardous materials and welding fumes. Continuous inhalation of harmful gases and particles can cause long-term health concerns, thus welders must use appropriate protective equipment and adhere to safety protocols [16]. Providing a safe working environment not only protects welders' health, but it also increases productivity and reduces the chance of accidents in dangerous situations [17].

From literature survey, it was found that limited research had been conducted on the safety and environmental conditions of welding fumes, particularly in Shielded Metal Arc Welding (SMAW) industries. Hence, this study aimed to evaluate the environmental and safety conditions in these industries, analyzing health risks from prolonged exposure to fumes and safety concerns through surveys of 16 locations and ranked using vikor algorithm. Key factors affecting worker well-being were identified based on this analysis.

2 Materials & Methods

In this study, survey data were obtained from 63 welders at 16 different welding companies around Tamil Nadu. The study asked about health problems associated with prolonged exposure to welding fumes, as well as workplace safety and environmental factors. Important aspects like as ventilation, equipment safety, PPE (personal protective equipment) use, and training were documented. Welders were interviewed and questioned about their everyday working conditions, health issues, and safety procedures. The obtained data was then analysed to identify essential health and safety aspects affecting worker well-being, with the VIKOR algorithm ranking [18].

2.1 Data collection

Interviews with welders provided information on demographic factors, working circumstances, labour relations, and welding surroundings. Clinical records were used to verify healthcare outcomes. A data registration form was created in accordance with relevant literature [19], and a pre-test was carried out to confirm the survey's validity.

2.2 Variables of the study

This study takes a variety of factors into account when assessing the health and safety of welders working in hazardous areas. Age, gender, and years of experience are important factors in determining a worker's risk exposure and capacity to manage safety standards. Welders' exposure to welding fumes is a major problem, as the frequency and length of such exposure affects their respiratory health. The use of personal protective equipment (PPE), such as masks and gloves, is crucial in reducing the risk of health problems, while proper ventilation in the workplace can decrease the accumulation of dangerous vapors. Environmental elements such as illumination, noise levels, and workspace temperature all contribute to the overall safety and comfort of welders. Inadequate lighting can cause eye strain, and excessive noise might harm hearing. job-related factors such as posture, weariness, and daily job duration are also significant, as bad posture and long work hours can result in musculoskeletal problems and an increased risk of accidents.

In terms of health outcomes, welders frequently experience respiratory disorders as a result of extended exposure to welding fumes, and their medical history can help predict the severity of these effects. The proper maintenance of welding equipment and the installation of safety indicators in the workplace are critical for reducing accidents and ensuring that workers are aware of potential hazards. The type of materials used in welding and the welding procedures utilised can also have an impact on environmental safety, with some materials releasing more toxic emissions. Finally, the level of safety training provided to workers, their

satisfaction with existing safety measures, and any history of workplace incidents are all important factors in assessing how well workers' health and safety are managed. Welders frequently develop minor health problems as a result of their exposure to welding fumes and the nature of their profession, many of which can be remedied with over-the-counter medications or simple treatments. Headaches are a common complaint, often caused by extended exposure to pollutants or insufficient ventilation, and can be treated with pain medicines such as paracetamol or ibuprofen. Inhaling fumes can cause nasal irritation, such as sneezing or a runny nose, which can be managed with saline nasal sprays or antihistamines.

Coughing is another common symptom of minor respiratory irritation, which can be alleviated with cough syrups or lozenges. Heat and UV radiation exposure while welding can cause skin irritation or moderate redness, which can be treated with soothing treatments such as aloe vera or calamine lotion. Similarly, modest UV-induced eye irritation or "arc eye" can produce discomfort and redness, which can be treated with artificial tears or over-the-counter eye medications. Throat lozenges, sprays, or warm saline gargles can help reduce sore throats caused by fume irritation. Staying hydrated, taking electrolyte supplements, and getting enough rest will typically alleviate fatigue caused by long-term exposure to fumes and working in hot conditions. Welders may also experience dry or cracked skin as a result of heat and sparks, which can be treated with over-the-counter moisturisers or barrier lotions to keep the skin hydrated. Nausea produced by inhaling fumes in poorly ventilated areas can be treated with simple therapies such as ginger-based medicines, water, or antacids.

Finally, minor burns from sparks or heat exposure are typical in welding and can be treated with antiseptic lotions or burn gels to avoid infection, as well as adhesive bandages to protect the region while it heals. These manageable difficulties underscore the significance of taking preventive steps, such as personal protective equipment and sufficient workplace ventilation, to limit their frequency.

2.3 Statistical Evaluation

In this study, the VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) technique was used to rank the numerous process parameters that affect welders' health and safety. The VIKOR approach is a multi-criteria decision-making (MCDM) strategy that assists in determining the optimal alternative when numerous competing criteria are present. It is especially beneficial when there are multiple elements impacting the decision, as in this situation, where welders' health and safety are affected by a variety of variables, including exposure to welding fumes, use of personal protective equipment (PPE), workplace ventilation, noise levels, and others.

The VIKOR technique evaluates both the best and worst possible performance values for each parameter. Each factor is assigned a positive ideal solution (highest possible performance) and a negative ideal solution (worst possible performance). The purpose is to determine how each process parameter (such as PPE use or ventilation quality) differs from the optimum solutions. The general formula for calculating the performance score of each choice for each criterion is as follows:

$$S_i = \sum_{j=1}^{m} w_j \times \frac{|x_{ij} - x_{j+}|}{|x_{j-} - x_{j+}|}$$

Where S_i is the performance score of the i-th alternative (in this case, each welding factory or worksite), w_j is the weight of the j-th criterion (e.g., ventilation, PPE use), x_{ij} is the performance value of the i-th alternative for the j-th criterion, x_{j+} and x_{j-} are the best and worst performance values for the j-th criterion, respectively.

Once the scores have been determined, the next step is to find a compromise solution by minimizing the gap between the ideal and anti-ideal solutions. This is accomplished by calculating two indices, Q_1 and Q_2, which add the weighted deviations of each element. The overall ranking of each process parameter or welding location is then calculated using these compromise options, with the best-ranked alternatives having the lowest values of Q_1 and Q_2.

The process can be mathematically represented as:

$$Q_1 = \lambda S_i + (1 - \lambda) R_i$$

The parameters S_i and R_i represent the distance from alternatives to the ideal and anti-ideal solutions, respectively, while λ is a parameter that balances the relevance of the two measurements. The options are then sorted, and the top-ranked characteristics are deemed the most important elements influencing worker health and safety.

The study used the VIKOR approach to identify and prioritise the most important workplace health and safety indicators, directing improvements in working conditions and welder safety standards.

3 Results & Discussions

Table 1 shows the information gathered from the questionnaire on the welders. The analysis of characteristics influencing welders' health and safety in shielded metal arc welding situations yielded enlightening results. Workers' average age was 35.5 years, with a standard deviation of 8.2, indicating a primarily mid-aged workforce with significant age distribution variation. Workers had an average of 10.2 years of experience, indicating a skilled labour force. The mean frequency of exposure to welding fumes was 6.5, with a relatively low standard deviation of 1.1, indicating continuous and protracted exposure among workers. This is consistent with the reported average welding fume exposure length of 7.0 hours per day, which poses severe health hazards.

Table 1 - Statistical Evaluation of Welders Data Collected from different working environments

Parameter	**Mean**	**Standard Deviation (SD)**	**Variance**
Age	35.5	8.2	67.24
Years of Experience	10.2	4.5	20.25
Ventilation Quality	3.9	1.3	1.69
Use of Personal Protective Equipment	4.2	0.8	0.64
Lighting Conditions	4.0	1.0	1.00
Noise Level in the Work Area	5.3	1.5	2.25
Welding Fume Exposure Time	7.0	2.2	4.84
Frequency of Exposure to Welding Fumes	6.5	1.1	1.21
Workplace Accidents	0.5	0.2	0.04
Safety Training Received	3.6	1.0	1.00
Health Impact of Welding Fumes	3.7	1.2	1.44
Maintenance of Welding Equipment	4.8	0.9	0.81
Posture During Work	3.8	1.0	1.00
Use of Safety Signs	4.4	1.1	1.21
Duration of Daily Work	8.0	1.5	2.25
Workplace Temperature	6.2	1.3	1.69
Welding Material Used	3.3	1.0	1.00
Chemical Exposure	2.5	1.4	1.96
Welding Technique (Manual or Automated)	4.1	0.7	0.49

Fatigue Level	6.0	1.8	3.24
Worker's Satisfaction with Safety Measures	4.5	1.2	1.44
Ergonomics of the Workspace	3.9	1.0	1.00
Shift Work	5.1	1.3	1.69
Shift Timing (Day or Night)	4.2	0.9	0.81
Overall Job Satisfaction	4.3	1.0	1.00

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The use of personal protective equipment had a moderate mean of 4.2, indicating partial compliance, although variability indicates inconsistent use. Ventilation quality and lighting conditions averaged 3.9 and 4.0, indicating areas for improvement to create safer and more comfortable work environments. Noise levels in the workplace were moderately high, with a mean of 5.3 and a considerable standard deviation of 1.5, emphasizing the importance of noise mitigation techniques. Posture at work scored 3.8, indicating potential ergonomic issues that could add to physical strain.

Safety training received had a mean of 3.6, indicating the need for improved training programs, while the use of safety signs averaged 4.4, indicating adequate application of visual aids for safety. Maintenance of welding equipment had a score of 4.8, showing adequate efforts to ensure equipment reliability. Chemical exposure had the lowest mean (2.5), indicating a significant area for control and safety improvement. Fatigue levels, with a mean of 6.0, highlighted the physical demands on workers, although worker satisfaction with safety measures was 4.5, suggesting moderate satisfaction. Factors such as workplace temperature, welding materials, and procedures had an average value of 3.3 to 6.2, representing varying employment conditions. Overall, while there are strengths in safety measures and experience levels, the high levels of welding fumes, moderate use of personal protective equipment, and weariness necessitate rapid attention to improve occupational health and safety results.

Details summarizing the 10 health issues, with statistical evaluations based on a sample of 63 welders are shown in Table 2. The evaluation includes the percentage of welders affected, the mean severity score (on a scale of 1–5, with 5 being most severe), the standard deviation (SD), and the variance for each issue.

Table 2 – Health issues identified from the welders

Health Issue	**% Affected**	**Mean Severity (1–5)**	**Standard Deviation (SD)**	**Variance**
Coughing	65% (41/63)	3.6	0.8	0.64
Nasal Irritation	60% (38/63)	3.5	1.0	1.00
Sore Throat	55% (35/63)	3.4	0.9	0.81
Skin Irritation	50% (32/63)	3.2	0.7	0.49
Minor Burns	50% (32/63)	3.3	0.8	0.64
Fatigue	80% (50/63)	4.2	0.8	0.64

Eye Irritation	75% (47/63)	4.0	0.6	0.36
Dry or Cracked Skin	45% (28/63)	3.1	1.1	1.21
Nausea	40% (25/63)	2.9	1.2	1.44
Headaches	70% (44/63)	3.8	0.9	0.81

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For each parameter, the formula was used to normalize values.

$$r_{ij} = \frac{x_{ij} - min(x_j)}{\max(x_j) - \min(x_j)}$$

where r_{ij} is the normalized value, x_{ij} is the actual value, and $\max(x_j)$ and $\min(x_j)$ are the criterion j's maximum and minimum values, respectively. This ensured that the data was scaled and comparable across all parameters.

Weighted normalized values were then calculated by allocating weights to each criterion according to its relevance. For this analysis, the weights were set at w=[0.5,0.3,0.2] for mean, standard deviation, and variance. The weighted normalized value (v_{ij}) for each parameter was determined using

$$v_{ij} = w_j \times r_{ij}$$

Following this, the utility (S_i) and regret (R_i) values for each alternative were calculated. The utility value (S_i) was obtained by summing the weighted normalized values across all criteria

$$S_i = \sum_{j=1}^{n} v_{ij}$$

Although the regret value R_i was calculated by determining the greatest weighted normalized value for each condition.

$$R_i = max_j(v_{ij})$$

Finally, the VIKOR index (Q_i) was calculated to rank the alternatives by adding the utility and regret values. The formula is given below

$$Q_i = v\frac{S_i - S^*}{S^- - S^*} + (1 - v)\frac{R_i - R^*}{R^- - R^*}$$

The majority criterion was weighted at v=0.5, with S and S^- representing the best and worst utility values, and R and R^- representing the best and worst regret values. This method involved ranking the alternatives and identifying the parameters that had the greatest impact on health and safety. Table 3 shows the calculated Si (Utility), Ri (Regret), and Qi (VIKOR Index) values for ten health conditions encountered by welders. These metrics rank the issues according to their severity and impact, with Skin Irritation, Minor Burns, and Sore Throat being the top three health concerns that require immediate attention.

Table 3 - Calculated S_i (Utility), R_i (Regret), and Q_i (VIKOR Index) values for the 10 health issues

Health Issue	**S_i**	**R_i**	**Q_i**
Nasal Irritation	0.549288	0.230769	0.539094
Minor Burns	0.305698	0.153846	0.175693
Sore Throat	0.425641	0.192308	0.355391
Coughing	0.421083	0.269231	0.450462
Skin Irritation	0.189459	0.115385	0.000003
Dry or Cracked Skin	0.484330	0.250000	0.493854
Eye Irritation	0.423077	0.423077	0.652619
Nausea	0.500000	0.300000	0.575798
Fatigue	0.651852	0.500000	1.000000
Headaches	0.579487	0.346154	0.721750

The VIKOR analysis provided substantial insights into the relative severity and prioritization of health issues encountered by welders exposed to shielded metal arc welding fumes. Skin irritation was identified as the most urgent of the ten health concerns studied, with the lowest Q_i value of 0.000003, indicating that it required immediate attention and treatment. Similarly, minor burns and sore throat, with Q_i values of 0.175693 and 0.355391, respectively, were rated second and third, emphasizing their importance in harming workers' health and indicating that these issues should be targeted for mitigation measures. Coughing (Q_i = 0.450462) and dry or cracked skin (Q_i = 0.493854) were also identified as moderate concerns, with rankings reflecting their

significance but lower impact when compared to the top three conditions. The Q_i scores for nose irritation (0.539094) and nausea (0.575798) identified them as health concerns that, while significant, were less critical than the higher-ranked conditions.

In contrast, eye irritation Q_i = 0.652619, headaches Q_i = 0.721750, and exhaustion Q_i = 1.000000 were ranked lower, implying that, while they represent health risks, their impact may be less rapid or severe than that of skin irritation or small burns. The high R_i value for weariness (0.500000) demonstrates its frequent occurrence among workers, making it a substantial source of long-term concern.These rankings create a clear prioritizing strategy for addressing health issues in welding workplaces. Immediate attention should be paid to the most critical issues, such as improving personal protective equipment, safety procedures, and ventilation quality, which might significantly reduce the prevalence and severity of these health problems. The findings highlight the need of proactive health management strategies in protecting welders' well-being.

4 Conclusions

The study shed light on the health and safety challenges that welders encounter when working in shielded metal arc welding situations. The findings emphasize the important need for focused interventions to address health issues, specifically skin irritation, small burns, and sore throats, which were identified as the top three concerns using the VIKOR technique. The health issues with the lowest Q_i scores have a major impact on workers and demand prompt action to reduce risks. Moderate issues, such as coughing, dry or cracked skin, nasal discomfort, and nausea, highlight the need for greater safety measures and better adherence to protective equipment use. Fatigue, despite being graded lower with a Q_i rating of 1.000000, is a significant long-term worry due to its persistent nature and potential for cumulative health impacts. Ventilation, posture, noise, and safety training were recognized as issues that needed attention to improve working conditions and overall safety. The study emphasizes the value of proactive safety management, which includes improving ventilation quality, assuring consistent use of personal protective equipment, and improving ergonomic and environmental circumstances. Prioritising interventions based on rankings allows stakeholders to effectively address significant health concerns and increase the well-being of welders in hazardous workplaces.

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