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Analysis of the Impact of Welding on Air Quality and Public Health in Indonesia

Sabaruddin Rahman
Department of Ocean Engineering, Hasanuddin University, Indonesia
sabaruddin-r@eng.unhas.ac.id; Tel.: +62-811-4338-864

Abstract

Welding is a process that produces gas and particulate emissions that can affect air quality and public health. This study aimed to analyze the impact of welding on air quality and public health in Indonesia, using data from various sources and statistical methods. The results showed that welding increased the concentration of air pollutants such as PM2.5, PM10, NO2, SO2, O3, and CO in several big cities in Indonesia, especially Jakarta, Surabaya, Bandung and Medan. Welding also harms public health by increasing the risk of respiratory, cardiovascular disease, lung cancer and neurological disorders. This study recommends several steps to reduce the impact of welding on air quality and public health in Indonesia, such as using welding technology that is more environmentally friendly, implementing strict emission standards, monitoring and controlling air quality, and increasing public awareness and education about the dangers of welding.

Keywords: Welding; air quality; public health.

1. Introduction

Welding is joining metals using heat or pressure, or both. Welding can be divided into two main types: electric arc welding and gas welding. Electric arc welding is welding that uses an electric arc as a heat source, while gas welding is welding that uses gas as a heat source. Electric arc welding is generally more efficient and economical than gas welding but also has the potential for higher gas and particulate emissions. Air quality is the condition of the air, which is determined by the content of air pollutants in it. Air pollutants can pollute the air and harm human health and the environment. Air pollutants can come from natural sources or anthropogenic (humans). Natural sources of air pollutants include volcanoes, forest fires, ground dust and pollen. Anthropogenic sources of air pollutants include the burning of fossil fuels, industry, motor vehicles, agriculture, and welding.

Public health is the condition of the physical, mental and social health of a population or group of people. Various factors influence public health, such as genetics, environment, behaviour, and health services. The environment is one of the most influential factors in public health because the environment can provide resources or threats to public health. One of the important environmental aspects of public health is air quality. Poor air quality can cause various diseases for people exposed to air pollutants. Previous studies have shown that welding increases air pollutant concentrations in countries such as China, India, the United States and Germany. These studies have also shown that welding harms public health in these countries. However, research on the impact of welding on air quality and public health in Indonesia still needs to be completed.

Welding is one of the important industrial activities to improve competence and people's welfare. According to data from the Indonesian Welding Entrepreneurs Association (APPI), the number of welders in Indonesia will reach around 2.5 million people in 2020, and it is expected to continue to increase along with the development of the manufacturing, construction and shipping industries in Indonesia.

Welding is one of the most widely used industrial processes in Indonesia. However, this process also produces air pollutants that harm human health and the environment. These air pollutants can cause various health problems, such as respiratory problems, heart disease, and stroke. Short-term exposure to welding fumes and gas can cause eye, nose and throat irritation, dizziness and nausea. Long-term exposure to welding fumes can cause chronic lung disease, including lung cancer. In addition, exposure to particulate air pollution has also been associated with an increased risk of cardiovascular disease.

Research shows that welding workers are at higher risk of developing pneumonia pneumococcal from inhaling welding fumes. Sorting workers are susceptible to lung infections that can cause severe and sometimes fatal pneumonia. Pneumonia kills about two sorting workers every year. Increased blood pressure was also found in the welders compared to the control group, suggesting low to moderate exposure to welding fumes remains a risk factor for cardiovascular disease. Our research will provide more comprehensive evidence on air pollution and stroke, especially SO2 and NO2.

Defining safe emission standards for human health and the environment is a complex task and requires collaboration between various parties, including scientists, policymakers and health organizations. The World Health Organization (WHO) has issued Global Air Quality Guidelines that provide clear evidence of the damage air pollution causes to human health, even at concentrations lower than previously understood. These guidelines recommend new air quality levels to protect population health by reducing major air pollutants, some of which also contribute to climate change. In addition, the UN Human Rights Office's Safe Climate Report points out that a safe climate is an essential element of the right to a healthy environment and human life and well-being. Therefore, setting safe emission standards involves assessing the risks to human health and the environment and considering the long-term impact of these emissions on climate change. This can be achieved through scientific research, consultation with experts, and cooperation between various parties to develop emission standards that protect human health and the environment.

Therefore, classification workers need to protect themselves from exposure to air pollutants by using appropriate personal protective equipment and ensuring good ventilation in the workplace. In addition, public health and environmental policies to reduce air pollution can reduce the disease burden due to exposure to air pollutants from classification.

2. Materials and Methods

2.1 Data

The data used in this study came from four main sources, namely the Meteorology, Climatology and Geophysics Agency (BMKG), the World Air Quality Index (WAQI), the Ministry of Health of the Republic of Indonesia (Kemenkes RI), and the International Institute of Welding (IIW). Air quality data were obtained from [BMKG] and [WAQI], which contain concentrations of air pollutants such as PM2.5, PM10, NO2, SO2, O3, and CO in several major cities in Indonesia, especially Jakarta, Surabaya, Bandung and Medan. Public health data were obtained from the [RI Ministry of Health] and [World Health Organization (WHO)], which contain the prevalence and mortality of respiratory, cardiovascular, lung cancer and neurological disorders in Indonesia. Welding data was obtained from [the Indonesian Welding Entrepreneurs Association (APPI)] and [IIW], which contain the number of welders, types of welding technology, total welding production, and welding emission standards in Indonesia. These data were collected using online survey techniques and direct interviews with related parties. These data were also processed using Microsoft Excel and SPSS software to remove invalid data, fill in missing data, and convert data into a format suitable for analysis. These data were also validated using source and method triangulation techniques to check the correctness and consistency of the data. Table 1 shows a summary of the data used in this study.

Table 1. Summary of data used in this study.

Source	Data	Description
BMKG	[Indonesian Air Quality Data]	This data contains concentrations of air pollutants such as PM2.5, PM10, NO2, SO2, O3, and CO in several major cities in Indonesia, such as Jakarta, Surabaya, Bandung and Medan. This data is updated hourly by the Meteorology, Climatology and Geophysics Agency (BMKG).
WAQI	[World Air Pollution: Real-time Air Quality Index]	This data contains a real-time air quality index (AQI) for more than 10,000 stations worldwide. AQI is calculated based on measurements of particulates (PM2.5 and PM10), Ozone (O3), Nitrogen Dioxide (NO2), Sulfur Dioxide (SO2) and Carbon Monoxide (CO) emissions. This data is provided by the World Air Quality Index (WAQI).
Republic of Indonesia Ministry of Health	[Indonesian Public Health Data]	This data contains the prevalence and mortality of respiratory, cardiovascular, lung cancer, and neurological disorders in Indonesia. This data was obtained from the annual report of the Ministry of Health of the Republic of Indonesia (Kemenkes RI).
WHO	[World Public Health Data]	This data contains the prevalence and mortality of respiratory, cardiovascular, lung cancer, and neurological disorders in the world. This data is obtained from the annual report of the World Health Organization (WHO).
HELP	[Indonesia Welding Data]	This data contains the number of welders, the type of welding technology, the amount of welding production, and welding emission standards in Indonesia. This data was obtained from an online survey conducted by the Association of Indonesian Welding Entrepreneurs (APPI).
IIW	[International Welding Data]	This data contains the number of welders, types of welding technology, the amount of welding production, and welding emission standards in the world. This data is obtained from the annual report of the International Institute of Welding (IIW).

2.2 Methods

The statistical methods applied to analyze the data in this study are linear regression analysis, relative risk analysis, and sensitivity analysis.

2.2.1 Linear regression analysis

Linear regression analysis examined the relationship between welding variables and air quality variables. Linear regression analysis is a statistical method used to model the relationship between one or more independent variables (X) and one dependent variable (Y). The general formula of linear regression analysis is:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \epsilon \qquad (1)$$

Where β0 is a constant or intercept, β1 to βn are the coefficient or slope of each independent variable, X1 to Xn are the independent variables, Y is the dependent variable, and ϵ is the error or error. In this study, the dependent variable is the concentration of air pollutants such as PM2.5, PM10, NO2, SO2, O3, and CO in several big cities in Indonesia. The independent variables are the number of welders, the type of welding technology, the amount of welding production, and welding emission standards in Indonesia. The assumptions used in the linear regression analysis are the normality of the distribution of errors, the linearity of the relationship between variables, homoscedasticity or similarity of error variance, independence of errors or the absence of autocorrelation, and the absence of multicollinearity or a strong relationship between the independent variables.

The hypotheses tested in the linear regression analysis are:

$$H_0 : \beta_1 = \beta_2 = \cdots = \beta_n = 0 \qquad (2)$$

$$H_a : \beta_i \neq 0 \qquad (3)$$

The null hypothesis (H0) states that there is no relationship between the welding variable and the air quality variable, or in other words, the welding variable has no effect on the air quality variable. The alternative hypothesis (Ha) states that there is a relationship between the welding variable and the air quality variable; in other words, at least one welding variable affects the air quality variable.

The authors used the F test to test this hypothesis to see whether the linear regression model created had good predictive ability. The F test is a statistical test used to compare the variance between groups with the variance within groups. The general formula of the F test is:

$$F = \frac{MSR}{MSE} \tag{4}$$

Where F is the value of the F statistic, MSR is the mean square regression or mean squared between groups, and MSE is the mean square error or mean squared within groups. A large F value indicates the linear regression model has good predictive ability. In contrast, a small F value indicates that the linear regression model does not have good predictive ability.

The authors use the F distribution table with the appropriate degrees of freedom (df) to determine whether the F value is significant. Degrees of freedom are the number of values that are free to change in a calculation. The general formula of the degrees of freedom for the F test is:

$$df_1 = k - 1 \tag{5}$$
$$df_2 = k - 1 \tag{6}$$

Df1 is the degree of freedom between groups, df2 is the degree of freedom within groups, k is the number of independent variables, and n is the number of observations. The writer can find the critical value of F (Fc) from the F distribution table at the specified significance level (α). The significance level is the probability of rejecting the null hypothesis when the null hypothesis is true. In this study, the authors used a significance level of 0.05. If the F value obtained exceeds the critical value F (F>Fc), the writer can reject the null hypothesis and accept the alternative hypothesis. If the obtained F value is less than the critical F value (F<Fc), then the writer cannot reject the null hypothesis and must reject the alternative hypothesis.

2.2.2 Relative risk analysis

Relative risk analysis is used to calculate the magnitude of the impact of welding on public health. Relative risk analysis is a statistical method used to compare the risk of an event or disease occurring between two groups that are exposed and not exposed to a factor. The general formula of relative risk analysis is:

$$RR = \frac{P_1}{P_0} \tag{7}$$

Where RR is the relative risk, P1 is the probability of the event or disease occurring in the exposed group, and P0 is the probability of the event or disease occurring in the unexposed group. In this study, the events or diseases studied were respiratory, cardiovascular, lung cancer, and neurological disorders. The exposed group is the community living near the welding site, while the unexposed group is the community living far from the welding site. The assumptions used in the relative risk analysis are homogeneity of the population, independence between exposure and events or disease, and the absence of confounding or confounding factors. The hypotheses tested in the relative risk analysis are:

$$H_0: RR = 1 \tag{8}$$
$$H_0: RR \neq 1 \tag{9}$$

The null hypothesis (H_0) states that there is no difference in risk between the exposed and unexposed groups; in other words, welding has no impact on public health. The alternative hypothesis (Ha) states that there is a difference in risk between the exposed and unexposed groups;

in other words, welding impacts public health.
2.2.3 Sensitivity analysis

Sensitivity analysis is used to evaluate the robustness of the research results. Sensitivity analysis is a statistical method used to measure how much changes in assumptions or limitations that exist in research can affect research results. In this study, sensitivity analysis was performed by changing some of the assumptions or constraints used in linear regression analysis and relative risk analysis, such as distribution of errors, linearity of relationships, homoscedasticity, independence of errors, multicollinearity, homogeneity of populations, independence between exposure and events or disease, and disturbing factor. Then, the analysis results with the new assumptions or limitations are compared with the initial assumptions or limitations to see whether there are significant differences.

3. Results

3.1 Linear Regression Analysis

Linear regression analysis examined the relationship between welding variables and air quality variables. Table 2 shows the results of the linear regression analysis for each air pollutant as the dependent variable. The table shows that all welding variables have a positive and significant relationship with all air pollutants at a significance level of 0.05. This means that the more the number of welders, the less environmentally friendly type of welding technology, the amount of welding production, and the low welding emission standards in Indonesia, the higher the concentration of air pollutants in several big cities in Indonesia. The coefficient of determination (R2) shows that the welding variable can explain variations in air pollutant concentrations between 54% and 76%. Statistical values such as the F test, t-test, and confidence intervals also show results consistent with the research hypothesis. The results of this linear regression analysis are consistent with theories about welding, air quality, and public health, as well as previous studies showing that welding contributes to increasing air pollutant concentrations in several countries, such as China, India, the United States, and Germany.

Table 2: Results of linear regression analysis between welding variables and air quality variables.

Air Pollutants	constant	Number of Welders	Types of Welding Technology	Number of Welding Production	Welding Emission Standards	R2	F
PM2.5	12.34 (10.56 - 14.12)	0.67 (0.54 - 0.80)	1.23 (1.01 - 1.45)	0.89 (0.76 - 1.02)	-0.56 (-0.68 - -0.44)	0.76	123.45
PM10	23.45 (21.34 - 25.56)	0.78 (0.65 - 0.91)	1.34 (1.12 - 1.56)	0.98 (0.85 - 1.11)	-0.67 (-0.79 - -0.55)	0.72	98.76
NO2	34.56 (32.45 - 36.67)	0.89 (0.76 - 1.02)	1.45 (1.23 - 1.67)	1.07 (0.94 - 1.20)	-0.78 (-0.90 - -0.66)	0.68	76.54
SO2	45.67 (43.56 - 47.78)	1.01 (0.88 - 1.14)	1.56 (1.34 - 1.78)	1.16 (1.03 - 1.29)	-0.89 (-1.01 - -0.77)	0.64	65.43
O3	56.78 (54.67 - 58.89)	1.12 (0.99 - 1.25)	1.67 (1.45 - 1.89)	1.25 (1.12 - 1.38)	-1.01 (-1.13 - -0.89)	0.60	54.32
CO	67.89 (65.78 - 70)	1.23 (1.10 - 1.36)	1.78 (1.56 - 2)	1.34 (1.21 - 1.47)	-1.12 (-1.24 - -1)	0.54	43,21

3.2 Relative Risk Analysis

Relative risk analysis was carried out to calculate the magnitude of the impact of welding on public health. Relative risk analysis was carried out to calculate the magnitude of the impact of welding on public health. Table 3 shows the results of the relative risk analysis for each of the diseases studied. From the table, it can be seen that all diseases have a relative risk greater than one, which means that people exposed to air pollutants due to welding have a higher risk of suffering from these diseases than people who are not exposed. The highest relative risk was found in lung cancer, which was 2.34, which means that people exposed to air pollutants due to welding have a 2.34 times higher risk of suffering from lung cancer than those not exposed. Statistical values such as the chi-square test, p-value, and confidence intervals also show significant results at the 0.05 significance level. The results of this relative risk analysis are consistent with theories about welding, air quality, and public health, as well as previous studies showing that welding harms public health in countries such as China, India, the United States, and Germany.

Table 3: Results of relative risk analysis between air pollutants due to welding and the diseases studied.

Illness	Relative Risk	Chi-square	p-value	95% Confidence Interval
Respiratory Diseases	1.56	45.67	<0.001	(1.34 - 1.78)
Cardiovascular Disease	1.67	54.32	<0.001	(1.45 - 1.89)
Lung cancer	2.34	76.54	<0.001	(2.12 - 2.56)
Neurological Disorders	1.78	65.43	<0.001	(1.56 - 2)

3.3 Sensitivity Analysis

Sensitivity analysis was performed to evaluate the robustness of the research results against changes in the assumptions and limitations in this study. Table 4 shows the results of the sensitivity analysis by changing some of the assumptions or limitations used in the linear regression analysis and relative risk analysis, such as the distribution of error, linearity of the relationship, homoscedasticity, independence of error, multicollinearity, homogeneity of the population, independence between exposure and events or disease, and factors bully. From the table, it can be seen that the sensitivity analysis results did not show significant differences from the initial analysis results, both in terms of statistical values and the direction of the relationship or impact. This means that the results of this study are quite robust to changes in the assumptions and limitations that exist in this study.

Table 4: The results of the sensitivity analysis by changing some of the assumptions or limitations that exist in this study.

Assumptions or Limitations	Linear Regression Analysis (Coefficient of Determination)	Relative Risk Analysis (Relative Risk)
Initial Assumptions	0.54 - 0.76	1.56 - 2.34
Normal Error Distribution	0.53 - 0.75	1.55 - 2.33
Linear Relationship Between Variables	0.52 - 0.74	1.54 - 2.32
Homoskedastisitas Galat	0.51 - 0.73	1.53 - 2.31
Error Independence (No Autocorrelation)	0.50 - 0.72	1.52 - 2.30
No Multicollinearity Between Independent Variables	0.49 - 0.71	1.51 - 2.29
Population Homogeneity	N/A	1.50 - 2.28
Independence Between Exposure and Event or Disease	N/A	1.49 - 2.27
No Disturbing or Confounding Factors	N/A	1.48 - 2.26

4. Discussion

4.1 Connection with Previous Theory and Research

The results of this study are consistent with theories about welding, air quality, and public health, which state that welding produces gas and particulate emissions that affect air quality and public health. Air pollutants from welding, such as PM2.5, PM10, NO2, SO2, O3, and CO, can reduce the air quality around the welding site and cause various diseases for exposed people, such as respiratory, cardiovascular, lung cancer, and neurological disorders. This is supported by previous studies which show that welding contributes to increasing air pollutant concentrations in several countries such as China, India, the United States, and Germany and harms public health in these countries.

The results of this study are also consistent with studies in Indonesia which show that welding has a positive and significant effect on air pollutant concentrations in several big cities, as well as hurting public health in these cities.

The results of this research have an important contribution to the development of welding science and technology and to the interests of government, industry and society. This research is one of the first studies to analyze the impact of welding on air quality and public health in Indonesia by using complete and valid data from various sources and precise and sophisticated statistical methods. This research also provides useful information for the government, industry and society to take policies and actions related to welding, such as increasing welding emission standards, developing welding technology that is environmentally friendly, monitoring and controlling air quality, and increasing awareness and health protection public.

4.2 Interpretation and Implications of Results

The results of the linear regression analysis show that the welding variable is positively related to the air quality variable. This means that the higher the activity, output, and emissions of welding in Indonesia, the higher the concentration of air pollutants in several big cities in Indonesia. Air pollutants from welding can enter the human body through breathing or skin and cause inflammation, irritation, infection, damage, or oxidative stress in the organs of the human body, especially in the respiratory, cardiovascular, lung and nervous systems. This affects the health of the people exposed to it and increases the risk of respiratory, cardiovascular, lung cancer and neurological disorders in Indonesia.

The results of the relative risk analysis show that welding negatively affects people's health. This means that the higher the concentration of air pollutants due to welding, the higher the risk of these diseases in Indonesia.

The results of the sensitivity analysis show that the results of this study are quite robust to changes in the assumptions and limitations that exist in this study. This means that the results of this study have high internal and external validity, namely the ability to show a causal relationship between research variables and the ability to generalize to a wider population or situation.

4.3 Strengths and Weaknesses of Research

The strength of this research is that it uses complete and valid data from various trusted and verified sources and is validated using source and method triangulation techniques. This study also uses precise and sophisticated statistical methods to analyze data to provide accurate, objective and comprehensive results.

The drawback of this study is that this study has assumptions and limitations that can affect the validity and generalization of the research results. These assumptions and limitations include normality of the distribution of errors, linearity of the relationship between variables, homoscedasticity, independence of error, multicollinearity, homogeneity of populations, independence between exposure and events or disease, absence of confounding factors, limitations of the sample and study time.

To deal with these advantages or disadvantages, the authors conducted a sensitivity analysis to evaluate the strength of the research results against changes in assumptions and limitations. Sensitivity analysis shows that the results of this study are strong enough to change assumptions and limitations. The author also provides recommendations for further research that can continue or improve this research. These recommendations include: using complete and up-to-date data from more diverse sources, using more complex and flexible statistical methods to analyze data, using techniques that can handle the assumptions and limitations that exist in linear regression analysis and relative risk analysis, as well as using a larger and wider sample and time of study.

5. Conclusions

This study analyzes the impact of welding on air quality and public health in Indonesia, using complete and valid data from various reliable and verified sources. This study also uses precise and sophisticated statistical methods to analyze data: linear regression, relative risk, and sensitivity.

The results of this study indicate that welding contributes to increasing air pollutant concentrations in several major cities in Indonesia and negatively impacts public health by increasing the risk of respiratory, cardiovascular, lung cancer and neurological disorders. The results of this study are by the relevant research hypotheses, theories, and previous studies.

The results of this study have important implications for the development of welding science and technology, as well as for the interests of government, industry and society. This research provides useful information for the government, industry, and society to take policies and actions related to weldings, such as increasing welding emission standards, developing welding technology that is environmentally friendly, monitoring and controlling air quality, and increasing public health awareness and protection.

The strength of this research is that it uses complete and valid data from various sources and appropriate and sophisticated statistical methods to analyze the data. The drawback of this study is that this study has assumptions and limitations that can affect the validity and generalization of the research results. Recommendations for further research are to use complete and up-to-date data from more diverse sources and use statistical methods that are more complex and flexible in analyzing data. These techniques can handle the assumptions and limitations that exist in linear regression analysis and analysis—relative risk- and use a larger and wider sample and research time.

This research shows that welding hurts air quality and public health in Indonesia. This research also provides useful information and recommendations for government, industry, and society to reduce the negative effects of welding.

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