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Research Article

Relationship between Sociodemographic Traits, Indoor PM2.5 Exposure, and Acute Respiratory Infection Risk in Aluminum Factory Communities, Deli Serdang

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Abstract: Acute Respiratory Infections (ARI) in the working area of Mulyorejo Public Health Center, where an aluminum factory is located, rank first among the ten most common diseases. This study aims to analyze the influence of sociodemographic characteristics and PM2.5 exposure on ARI complaints in the aluminum factory area of Payageli Village, Deli Serdang Regency. The cross-sectional observational study involved 160 housewives living within a radius of 10–1500 meters from the factory's chimney. The analysis included univariate, bivariate, and multivariate methods. Results showed that 58.1% of respondents experienced ARI symptoms in the past month. The average ambient (outdoor) PM2.5 concentration measured from three sampling points was 12.3 μg/m³, which did not exceed the WHO standard (<15 μg/m³). The highest concentration was recorded in the southern direction (15.5 μg/m³). Bivariate analysis indicated that education ($p = 0.010$), direction of house location ($p = 0.001$), and indoor PM2.5 concentration ($p = 0.006$) were significantly associated with ARI. Multivariate logistic regression analysis showed that the most dominant factor influencing ARI was indoor PM2.5 concentration ($p = 0.039$), followed by education ($p = 0.013$) and direction of house location ($p = 0.001$). This study provides a scientific basis for air quality control and housing environment improvement to reduce the risk of environmentally related diseases in industrial zones.

Keywords: Acute Respiratory Infection; Aluminum Factory; Deli Serdang Regency; PM2.5; Payageli Village.

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1. Introduction

Indoor air pollution can affect health both directly and in the long term. Immediate impacts often include irritation of the throat, nose, and eyes, accompanied by symptoms such as nausea and headaches, muscle pain or fatigue, as well as respiratory disorders such as asthma, flu, hypersensitive pneumonia, and other viral infections (USEPA, 2024). West Papua recorded the highest incidence of pneumonia (129.1%), followed by DKI Jakarta (104.5%). Meanwhile, North Sumatra ranked 29th with an incidence rate of 15.8% and a Case Fatality Rate (CFR) of 0.14%. This achievement aligns with the target set in the Strategic Plan (Renstra), which aims for 80% coverage in the pneumonia or acute respiratory infection (ARI) control program (Pertiwi, 2021).

Environmental factors inside the home play an important role in increasing the risk of ARI (Pakhrizki, 2023). The physical air quality within the home reflects various parameters such as humidity level, lighting, air temperature, and airborne particle concentration. According to the Regulation of the Minister of Health of the Republic of Indonesia (Permenkes RI) No. 1077, healthy home standards are determined by several physical factors, including a minimum lighting level of 60 lux, air humidity between 40% and 60%, temperature ranging from 18°C to 30°C, and PM2.5 concentration not exceeding 35 μg/m³ over 24 hours (Sartika, 2022).

Particulate Matter (PM2.5) refers to fine particles with a diameter of less than or equal to 2.5 micrometers. According to Siregar and Amri (2022), PM2.5 generally originates from external sources such as fuel combustion, industrial activities, and transportation. However, indoor sources also contribute, including the use of biomass fuels for cooking, smoking habits, and burning mosquito repellents (Permenkes No. 1077 on Guidelines for Indoor Air Sanitation).

In 2016, WHO stated that exposure to PM2.5 can cause inflammation in the respiratory system, leading to disorders such as ARI, Chronic Obstructive Pulmonary Disease (COPD), stroke, lung cancer, ischemic heart disease, and premature death. Therefore, this study aims to analyze the effects of respondents' sociodemographic characteristics and indoor PM2.5 exposure on the incidence of ARI, particularly in the aluminum factory area of Deli Serdang Regency.

2. Materials and Method

Indoor air pollution can affect health both directly and in the long term. Immediate impacts often include irritation of the throat, nose, and eyes, accompanied by symptoms such as nausea and headaches, muscle pain or fatigue, as well as respiratory disorders such as asthma, flu, hypersensitive pneumonia, and other viral infections (USEPA, 2024). West Papua recorded the highest incidence of pneumonia (129.1%), followed by DKI Jakarta (104.5%). Meanwhile, North Sumatra ranked 29th with an incidence rate of 15.8% and a Case Fatality Rate (CFR) of 0.14%. This achievement aligns with the target set in the Strategic Plan (Renstra), which aims for 80% coverage in the pneumonia or ARI control program (Pertiwi, 2021).

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Fig 1. Map of Household Sample Distribution, Ambient Air Measurement Samples, and Incidence of ARI among Housewives in the Aluminum Factory Area, Deli Serdang Regency.

The ambient air samples were measured using the Direct Reading method with a Portable Particle Counter. Before measuring the ambient air samples, it was necessary to first measure temperature, humidity, wind speed, and wind direction. The temperature and humidity inside the residents' houses were measured using a digital measuring devicethat simultaneously records both humidity and temperature (Humidity Meter and Hygrometer Thermometer).

Next, the PM2.5 concentration inside the sampled households was measured using an Air Quality Detector 6 in 1, which can measure six indicators of air pollution: carbon dioxide (CO_2), carbon monoxide (CO), formaldehyde (HCHO), total volatile organic compounds (TVOC), PM2.5, and PM10.

After the measurements were conducted, the data were collected and analyzed using univariate and bivariate analyses with the Chi-square test and Mann-Whitney test, followed by multivariate analysis using linear regression..

3. Results and Discussion

Frequency Distribution of Sociodemographic Characteristics

Table 1. Distribution of Age, House Distance, and Indoor PM2.5 Concentration Characteristics in the Aluminum Factory Area, Payageli Village, Deli Serdang Regency, 2025.

Physical Component Variables	Min	Max	Mean	Std. Deviation
Age (Years)	**21**	**80**	**47,56**	**13,703**
Distance of house (Meters)	**50**	**1000**	**483,44**	**252,759**
Indoor PM2.5 Concentration (μg/m³)	**20**	**69**	**26,66**	**7,236**

The distribution table above shows that the average age of housewives is 47.56 years, with the youngest being 21 years old and the oldest 80 years old. The average distance between houses and the chimney point is 483.44 meters, ranging from a minimum of 50 meters to a maximum of 1,000 meters. The indoor PM2.5 concentration has an average value of 26.66 μg/m³, with a minimum of 20 μg/m³ and a maximum of 69 μg/m³. The average indoor PM2.5 level is still below the quality standard set by Government Regulation (PP) No. 21 of 2022 (<55 μg/m³).

Distribution of ARI Incidence

Table 2. Frequency Distribution of ARI Incidence among Respondents in the Aluminum Factory Area, Payageli Village, Deli Serdang Regency, 2025.

Respondent Characteristics	n = 160	100 %
Incidence of ARI		
Yes	**93**	**58,1**
No	**67**	**41,9**

The frequency distribution table of ARI incidence above shows that out of 160 respondents, 93 people (58.1%) experienced ARI, while 67 people (41.9%) did not experience ARI within the last month.

Distribution of PM2.5 Concentration at Three Ambient Air Sampling Points (Outdoor)

Table 3. Average PM2.5 Concentration at Three Ambient Air Sampling Points (Outdoor).

Average PM2.5 Concentration	1st Measurement Result (4 hours)	2nd Measurement Result (4 hours)	Mean (μg/m³)
Sample 1 (Southwest Direction)	**12**	**10**	**11,0**
Sample 2 (West Direction)	**10**	**11**	**10,5**
Sample 3 (South Direction)	**16**	**15**	**15,5**
Total Average			**12,5**

The table above shows that the highest PM2.5 concentration was recorded at the southern point, with an average of 15.5 μg/m³, followed by the southwestern point with an average of 11.0 μg/m³, and the lowest at the western point with 10.5 μg/m³. The overall average concentration from the three measurement points (12.5 μg/m³) is still below the quality standard set by Government Regulation (PP) No. 21 of 2022 (<55 μg/m³).

Average Results of Ambient Air PM2.5 Concentration Measurements

The results of ambient air sample measurements (Table 5) at three locations (West, Southwest, and South) show that the Western point (300 meters) had a PM2.5 concentration of 10.5 μg/m³, with 69 respondents (43.1%) interviewed in this area out of a total of 160 respondents. The Southwestern point (300 meters) recorded a concentration of 11.0 μg/m³, with 43 respondents (26.9%). The Southern point (100 meters) showed the highest PM2.5 concentration of 15.5 μg/m³, with 48 respondents (30%) interviewed in this area.

Table 4. Ambient Air Quality at Three Sampling Locations.

Ambient Air Quality	Measurement Result
Distance from the Factory Chimney Source	
West Point	**300 meter**
Southwest Point	**300 meter**
South Point	**100 meter**
Average Wind Speed (m/s)	
West Point	**4,1 m/s**
Southwest Point	**3,75 m/s**
South Point	**4,45 m/s**
Average Relative Humidity (%)	
West Point	**65 – 75 %**
Southwest Point	**65 – 75 %**
South Point	**65 – 75 %**
Dominant Wind Direction	
West Point	**Toward the West**
Southwest Point	**Toward the West**
South Point	**Toward the West**
Average Ambient Air Temperature (°C)	
West Point	**28 – 32 ^{0}C**
Southwest Point	**28 – 32 ^{0}C**
South Point	**28 – 32 ^{0}C**
Air Sample Location Coordinates	
West Point	**N 03^0 35' 29.7" E 098^0 35' 47.9"**
Southwest Point	**N 03^0 35' 21.4" E 098^0 35' 54.7"**
South Point	**N 03^0 35' 28.0" E 098^0 36' 04.2"**

Average Wind Speed and Dominant Wind Direction

The wind speed at the western measurement point was 4.1 m/s, at the southwestern point 3.75 m/s, and at the southern point the highest, 4.45 m/s. The dominant wind direction from all three measurement points was from the northeast toward the west (Table 5).

Temperature and Relative Humidity

The average air temperature at the three measurement points ranged from 28–32°C. This consistent temperature indicates relatively stable weather conditions during the measurement period. The relative humidity at the three measurement points was also quite stable, ranging from 65–75% (Table 5).

Based on the cross-tabulation table of sociodemographic characteristics and ARI incidence (Table 17), it was found that within the past month, housewives aged ≥45 years—55 people (60.4%) experienced ARI, while 36 (39.6%) did not. In the <45 years age group, 38 people (55.1%) experienced ARI and 31 (44.9%) did not. The correlation analysis using the Chi-square test showed a p-value = 0.496 ($p > 0.05$), indicating no significant relationship between age and ARI incidence.

Based on respondents' education levels, housewives with primary to junior high school education (SD–SMP)—51 people (68.9%) experienced ARI and 23 (31.1%) did not. In the senior high school to higher education group (SMA–University), 42 people (48.8%) experienced ARI and 44 (51.2%) did not. The correlation analysis using the Chi-square test showed a p-value = 0.010 ($p < 0.05$), indicating a significant relationship between education level and ARI incidence. This means that mothers with lower education levels tend to have a higher risk of experiencing ARI.

Based on respondents' income levels, in the group with income below the regional minimum wage (RMW), 79 people (58.1%) experienced ARI and 57 (41.9%) did not. In the group with income above the RMW, 14 people (58.3%) experienced ARI and 24 (41.7%) did not. The Chi-square correlation test showed a p-value = 0.982 ($p > 0.05$), meaning there was no significant relationship between income level and ARI incidence.

Based on the distribution of ARI incidence by residential direction, housewives living in the southwest direction experienced ARI in 37 cases (86.0%), while 6 (14.0%) did not. In the west direction, 33 people (47.8%) experienced ARI and 36 (52.2%) did not. In the south direction, 23 people (47.9%) experienced ARI and 25 (52.1%) did not. The Chi-square test showed a p-value = 0.001 ($p < 0.05$), indicating a significant relationship between the house direction and ARI incidence. This means that mothers living in the southwest direction tend to have a higher risk of experiencing ARI.

Based on the distribution of ARI incidence by distance from the aluminum factory, housewives living less than 500 meters from the factory chimney—46 people (58.2%) experienced ARI and 33 (41.8%) did not. For respondents living more than 500 meters away, 47 people (58.0%) experienced ARI and 34 (42.0%) did not. The Chi-square test showed a p-value = 0.979 (p > 0.05), indicating no significant relationship between the distance of the house from the factory and ARI incidence.

Table 5. Relationship Between Sociodemographic Characteristics and the Incidence of ARI Among Respondents in the Aluminum Factory Area, Payageli Village, Deli Serdang Regency, 2025.

Individual Characteristics	Incidence of ARI						*p-value*
	Yes		No		Total		
	n	%	n	%	N	%	
Age							
≥ 45 years	**55**	**60,4**	**36**	**39,6**	**91**	**100**	**0,496**
< 45 years	**38**	**55,1**	**31**	**44,9**	**69**	**100**	
Education							
SD – SMP	**51**	**68,9**	**23**	**31,1**	**74**	**100**	**0,010**
SMA - PT	**42**	**48,8**	**44**	**51,2**	**86**	**100**	
Income level							
< RMW	**79**	**58,1**	**57**	**41,9**	**136**	**100**	**0,982**
> RMW	**14**	**58,3**	**10**	**41,7**	**24**	**100**	
House Location Direction							
Southwest	**37**	**86,0**	**6**	**14,0**	**43**	**100**	**0,001**
West	**33**	**47,8**	**36**	**52,2**	**69**	**100**	
South	**23**	**47,9**	**25**	**52,1**	**48**	**100**	
House Distance							
< 500 meter	**46**	**58,2**	**33**	**41,8**	**79**	**100**	**0,979**
≥ 500 meter	**47**	**58,0**	**34**	**42,0**	**81**	**100**	

Table 7. Relationship Between Indoor PM2.5 Concentration and the Incidence of ARI Among Respondents Living in the Aluminum Factory Area, Payageli Village, Deli Serdang Regency, 2025.

Independent Variable	ARI Incidence			*p-value*
	Yes	No	Total	
Indoor PM2.5 Concentration	**93**	**67**	**160**	**0,006***

Based on the Mann-Whitney test results analyzing the relationship between PM2.5 concentration and the incidence of ARI among 160 housewives living in the aluminum factory area of Payageli Village, Deli Serdang Regency in 2025, it was found that the significant variable was PM2.5 concentration (Table 7).

The relationship between indoor PM2.5 concentration and ARI incidence showed a significant association between higher indoor PM2.5 concentration and the occurrence of ARI (p = 0.006). This means that housewives living in homes with PM2.5 concentrations greater than 27 $\mu g/m^3$ are at a higher risk of experiencing ARI.

The independent variables included in the multivariate analysis were education, house location direction, and indoor PM2.5 concentration (Table 7). These variables were entered into a multiple linear regression model using the Backward LR method.

Based on the multiple logistic regression analysis, among the four variables tested, the most dominant factor influencing ARI incidence was indoor PM2.5 exposure, with an Odds Ratio (Exp(B)) of 5.370, meaning that the likelihood of experiencing ARI is five times higher. The Confidence Interval (CI) for the Odds Ratio ranged from 1.088 to 26.507, indicating that the CI does not cross 1, thus the effect of the variable is considered significant.

Another factor influencing the risk of ARI was the house location direction (Odds Ratio = 0.420). Statistically, since the p-values of the three variables were < 0.05 and the CI of the Odds Ratios did not include 1, it can be concluded that all three variables significantly affect the incidence of ARI among respondents living in the aluminum factory area.

Table 8. Selection Results from Bivariate to Multivariate Analysis.

Independent Variable	P value < 0,05
Education	**0,010**
Direction of House Location	**0,001**
Indoor PM2.5 Concentration	**0,006**

Based on the results of the multiple logistic regression test (Table 7), to estimate the probability of ARI occurrence for an individual with the specified category on all variables, the multiple logistic equation is used, substituted into the probability formula, and then the exponential value is calculated. A probability of ARI occurrence of 96.47% means that when the independent variables (location, education, and indoor PM2.5) are each assigned the value 1 (coded = 1), the likelihood that an individual will experience ARI is extremely high — nearly certain.

In practical terms, this indicates that the combination of these factors exerts a very strong influence on ARI risk, so an individual with that profile has a very high chance of developing ARI. A probability approaching 1 signals an almost-certain risk, highlighting the importance of interventions or preventive measures targeting these factors to reduce ARI risk.

Discussion

The sociodemographic characteristics of respondents living around the aluminum factory in Payageli Village provide a significant overview of the social and economic profile of the community that serves as the focus of this study. The age distribution of 160 housewives showed that the majority, 56.9%, were aged ≥ 45 years. This composition indicates that most housewives are within the productive age group, potentially active both socially and economically in the residential areas surrounding the aluminum factory.

The respondents' educational backgrounds varied, with the largest proportion being those with an elementary to junior high school education level, totaling 74 individuals (46.3%), while 86 individuals (53.8%) had attained a senior high school to higher education level. This shows that although a majority have reached secondary education, a considerable number of respondents have only completed basic education. This condition reflects limited access to education and the socioeconomic constraints of the surrounding community, which in turn affect their employment opportunities and understanding of environmental health issues (Nawawi, 2017)

Table 9. Summary of the Results of Multivariate Multiple Logistic Regression Analysis Using the Backward LR Method.

Variable	B	P (Sig.)	Exp (B)	95% C.I.for EXP(B)	
				Lower	Upper
Direction of House Location	**-.687**	**.000**	**.420**	**.262**	**.674**
Education	**.877**	**.013**	**2.403**	**1.202**	**4.805**
Indoor PM2.5 Concentration	**1.681**	**.039**	**5.370**	**1.088**	**26.507**
Constant	**1.616**	**.003**	**5.034**		

Based on income levels, 85% of respondents earned below the Deli Serdang District Minimum Wage (RMW) of IDR 3,732,906, while only 15% earned above that threshold. This indicates that most residents belong to the lower-middle economic class, which may influence their quality of life, access to healthcare services, and capacity to cope with risks resulting from industrial pollution.

Based on the direction of house locations, the majority of respondents' homes were located to the west (69 houses or 43.1%), followed by the south (48 houses or 30%) and the southwest (43 houses or 26.9%). This distribution reflects the settlement pattern around the factory, which is relevant for understanding air pollution exposure patterns. The distribution of residential distances from the aluminum factory showed that 79 houses (49.4%) were located less than 500 meters from the factory chimney, while 81 houses (50.6%) were located 500 meters or more away. This indicates that many respondents live close to the pollution source, potentially increasing their exposure to industrial pollutants. Therefore, special attention is needed to control health risks in these areas.

Measurements of PM2.5 concentrations and ambient air meteorological components at three sampling points (West, Southwest, and South) revealed important variations that need to be analyzed in the context of meteorological conditions and potential pollution sources around the study site. The southern sampling point showed the highest PM2.5 concentration of 15.5 $\mu g/m^3$, compared to 10.5 $\mu g/m^3$ in the west and 11.0 $\mu g/m^3$ in the southwest. Since the dominant wind direction during the measurement month (September) tended toward the west and southwest, respondents living in these directions were at greater risk of PM2.5 exposure originating from the factory.

The geographical characteristics of the three air sampling points differed according to ambient air sampling criteria, which avoid locations with tall buildings, dense trees, or heavy traffic areas. At the southern point, sampling was conducted in rice fields near residential areas, about 100 meters from the factory chimney. At the southwest point, measurements were taken in a vacant open area within a residential neighborhood, approximately 300 meters from the chimney. The western point was located in an open residential area also about 300 meters away.

However, another factor likely influencing the relatively low PM2.5 concentrations at all three points was the dense vegetation—trees and shrubs—surrounding the factory's perimeter, which borders a river. These plants play an important role in absorbing (absorption) and trapping (adsorption) PM2.5 particulate pollutants. In addition to these physical factors, meteorological conditions also significantly affect pollutant dispersion.

The wind speed at the southern sampling point, which was the highest (4.45 m/s), played a significant role in the dispersion of PM2.5 particles. According to Seinfeld and Pandis (2016), higher wind speeds can accelerate the migration of particulate pollutants, leading to the accumulation of concentrations in downwind areas, in this case, the southern direction. This condition supports the finding that the southern point exhibited the highest PM2.5 concentration, despite potential deposition due to high relative humidity.

The relative humidity, ranging from 65–75% across the three points, played a complex role in PM2.5 dynamics. High humidity causes pollutant particles to absorb water vapor and undergo coagulation, which promotes deposition and reduces airborne particle concentration (Perdana, Pangastuti, & Haryanto, 2023). However, this effect appeared to be less effective in lowering PM2.5 levels at the southern point, likely due to the proximity of the pollution source, as the factory chimney was located ≤100 meters from the sampling site.

The dominant wind direction, blowing from northeast to west, was also an important factor in analyzing pollutant distribution. Pollutants emitted from the factory chimney located in the northeast could be carried by the wind toward residential areas in the western and southwestern directions. This aligns with the air pollution dispersion theory, which states that wind direction and speed are key determinants in the spread of contaminants in ambient environments (Turner, 1994).

The ambient air temperature, consistently ranging between 28–32°C at the three points, reflects a relatively stable atmospheric condition during the measurement period. According to Perdana et al. (2023), higher temperatures can enhance air mixing and reduce the likelihood of temperature inversion, thereby facilitating the dispersion of PM2.5 pollutants into a wider atmospheric layer. This factor may explain why PM2.5 concentrations at the western and southwestern points were not higher.

The results of this study support the pollutant dispersion model based on the Gaussian plume theory, which estimates pollutant concentration distribution as a function of distance, wind speed, and atmospheric conditions (Turner, 1994). Meteorological conditions, particularly wind speed and dominant wind direction, have a direct influence on PM2.5 dispersion patterns. In addition, humidity and temperature as microclimatic variables also affect the mechanisms of pollutant deposition and dispersion.

The frequency distribution of ARI (Acute Respiratory Infection) cases showed that 58.1% of respondents experienced ARI, while 41.9% did not within the past month. This indicates a relatively high prevalence of ARI among the sample population, particularly housewives who spend more time at home and are thus more susceptible to exposure from aluminum factory emissions.

These results are consistent with findings from a study conducted in the aluminum smelting industrial area in Cilincing, which reported a high incidence of ARI due to air pollution from aluminum processing industries, particularly fine aluminum dust particles (<2.5 microns) that can impair lung function (PTG Enviro, 2018). Another study also reported a high prevalence of ARI among workers in aluminum factory environments, where exposure to dust and toxic substances plays a major role (Ardianto, 2009).

According to the epidemiological triad, the occurrence of diseases, including ARI, is influenced by the interaction between host, agent, and environmental factors (Aristatia & Yulyani, 2021). In the aluminum factory area, the agent, in the form of air pollutants such as PM2.5 dust and hazardous substances, acts as the direct cause of ARI. Meanwhile, unfavorable environmental conditions (such as poor housing quality and continuous exposure to air pollution) exacerbate the risk. The host, referring to an individual's health condition and immune system, also determines the severity of symptoms.

Based on the distribution of ARI incidence by age group, within the past month, 60.4% of housewives aged ≥ 45 years experienced ARI, while 39.6% did not. Among respondents under 45 years old, 55.1% experienced ARI and 44.9% did not. The Chi-Square correlation test yielded a p-value = 0.496 ($p > 0.05$), indicating no significant relationship between age and the incidence of ARI.

ARI commonly affects vulnerable age groups, such as children under five and the elderly, due to their weaker immune systems. Several studies have also reported an increased risk of ARI in older adults resulting from declining immune function and other risk factors. However, in this study, there was no significant association between age and ARI incidence, which may be attributed to the influence of other factors beyond age, such as environmental conditions and behavioral aspects (WHO, 2018).

Housewives with an education level of elementary to junior high school (SD–SMP) experienced ARI in 68.9% of cases, while 31.1% did not. Meanwhile, those with senior high school to higher education (SMA–University) had 48.8% experiencing ARI and 51.2% not experiencing ARI. Correlation analysis showed a significant relationship between education level and ARI incidence ($p = 0.010$; $p < 0.05$).

The finding that education level significantly influences ARI occurrence aligns with social and health theories, which state that education is an important social determinant of health. Higher education levels generally correlate with better knowledge and disease prevention practices, including understanding risk factors and preventive measures against respiratory infections (Nur Syamsi, 2020).

The data indicate that the distribution of ARI (Acute Respiratory Infection) cases among families based on income levels is relatively even—around 58% in both income groups, ≤ Rp. 3,732,906 and > Rp. 3,732,906. A p-value of 0.982 suggests that there is no significant difference between income level and ARI incidence.

This finding is consistent with the study by Syafarilla, Zulfitri, and Wahyuni (2017), which also reported no significant relationship between a family's socioeconomic status and ARI incidence among children under five. However, it contrasts with Sibagariang (2023), who found that families with lower income levels tended to experience higher ARI incidence due to limitations in meeting nutritional needs and maintaining household hygiene, both of which affect the immune system of family members.

Cross-tabulation results showed a significant difference in ARI cases based on the directional location of respondents' houses. In the southwest area, 37 respondents (86%) experienced ARI, while only 6 (14%) did not. Meanwhile, in the west area, the proportion of ARI sufferers decreased to 33 respondents (47.8%), with 36 respondents (52.2%) not affected. Similarly, in the southern area, 23 respondents (47.9%) experienced ARI, while 25 (52.1%) did not. The Mann-Whitney test produced a p-value of 0.008 ($p < 0.05$), indicating a statistically significant relationship between house direction and ARI incidence, suggesting that this pattern did not occur by chance.

This significant difference likely reflects the dispersion pattern of pollutants from the aluminum factory, which tends to concentrate more in the southwest area, thereby increasing the ARI risk among residents in that direction. This environmental factor highlights how the geographic characteristics of residential areas play a crucial role in determining pollutant exposure levels and their health impacts on communities surrounding the factory (Ikawati & Lestari, 2018).

Based on the distance between houses and the aluminum factory chimney, it was found that among housewives living less than 500 meters from the chimney, 58.2% experienced ARI while 41.8% did not. For respondents living more than 500 meters away, 58.0% experienced ARI while 42.0% did not. The Chi-Square test yielded a p-value of 0.979 ($p > 0.05$), indicating no significant relationship between house distance and ARI incidence.

According to the epidemiologic triad theory, environmental factors are one of the key aspects influencing disease occurrence, including ARI (Safitri, 2023). Factors such as air pollution from industrial activities can increase ARI risk in surrounding communities. However, this study shows that the distance of houses from the aluminum factory does not significantly affect ARI incidence.

The occurrence of ARI represents a complex interaction among the agent, host, and environmental factors. Therefore, the influence of factory distance should be analyzed in conjunction with in-house environmental conditions and residents' behavioral factors (Syahaya, 2021).

Based on the results of the Mann-Whitney test between indoor PM2.5 concentration in respondents' homes and the incidence of Acute Respiratory Infection (ARI), there was a significant relationship between high indoor PM2.5 concentration and ARI occurrence ($p = 0.006$, $p < 0.05$). This indicates that housewives living in environments with high PM2.5 concentrations are at greater risk of experiencing ARI.

The multivariate analysis using the Backward LR (Likelihood Ratio) method was employed to examine the influence of several independent variables that met the criteria ($p < 0.05$). The results of this multiple regression analysis provide an in-depth overview of the factors that significantly affect the incidence of ARI among residents living near the aluminum factory. Findings indicate that the location orientation of the house, education level, and indoor PM2.5 exposure significantly influence ARI risk.

The house location orientation variable was highly significant ($p = 0.000 < 0.05$) with an odds ratio (OR) = 0.420, which is less than 1, and a negative B coefficient (-0.867). This shows that respondents living in houses located in the dominant wind direction from the factory chimney (southwest) have a 0.420 times lower chance of developing ARI compared to those living in other directions. The negative B coefficient (-0.867) indicates that for each 0.8-unit increase in the location variable (e.g., moving from a high-risk wind direction to a location farther from the dominant wind), the log odds of ARI occurrence decrease by 0.420. This is consistent with OR < 1, which reflects a protective effect. In other words, the more optimal the house's location (not in the dominant wind direction, southwest), the significantly lower the likelihood of ARI among occupants.

Previous studies have shown that factors such as wind direction, house location relative to emission sources, and adequate ventilation also determine the level of protection or risk of ARI (Smith et al., 2023; WHO, 2018). Houses that are not in the path of pollutant-carrying winds or that have good air circulation tend to have lower ARI incidence. These findings support environmental and epidemiological theories emphasizing the importance of housing conditions in preventing respiratory diseases.

The education variable also had a significant effect ($p = 0.013$) with an odds ratio (OR or Exp(B)) of 2.403, meaning that the likelihood of ARI occurrence was nearly 2.4 times higher among housewives with low education levels (elementary–middle school). The B coefficient of 0.877 indicates a positive relationship, meaning that low education is associated with an increased probability of ARI occurrence. The phenomenon that education level significantly affects ARI incidence aligns with social and health theories stating that education is an important social determinant of health. Higher education generally correlates with better knowledge and practices in disease prevention, including understanding risk factors and how to avoid respiratory infections (Nur Syamsi, 2020).

The indoor PM2.5 exposure variable also showed a significant result ($p = 0.039 < 0.05$) with an odds ratio of 5.370, indicating that the risk of ARI increases up to 5.8 times with rising indoor PM2.5 concentrations. The B coefficient = 1.681 signifies a strong positive relationship between indoor PM2.5 exposure and ARI.

These results underscore that fine particulate pollutants in indoor air are a determinant of ARI risk. Theoretically, this can be explained by the model of pollutant exposure effects, which cause mucosal irritation, inflammatory reactions, and increased susceptibility to acute respiratory infections (Dominici et al., 2006; Wahyudi, 2023). These findings are consistent with respiratory and pathophysiological theories of ARI, which state that PM2.5 particles can penetrate deep into the alveoli, triggering inflammation and reducing immunity (Pope & Dockery, 2006; WHO, 2021). Similar studies by Nambo Banjaran (2023) also found a significant association between PM2.5 levels and ARI ($p = 0.006$), supporting the current study's results.

These findings support the theoretical framework of the ecological health approach, which integrates physical and biological environmental factors as key determinants of respiratory diseases (McMichael, 2013). Exposure to fine particulate pollutants (PM2.5), especially indoors, is a health risk that must be addressed, while good housing conditions act as a protective factor, reducing the penetration and effects of these particles.

5. Conclusion

The importance of analyzing sociodemographic characteristics and indoor PM2.5 concentrations as key parameters lies in improving quality of life, particularly in preventing ARI in the aluminum factory area of Payageli Village. This study demonstrates that education level, house location, and indoor PM2.5 exposure are significantly associated with ARI occurrence.

Efforts to mitigate this risk can include optimizing the control of fixed emission sources, increasing public education to promote behaviors that prevent ARI in industrial areas—such as improving household environmental hygiene and using masks during periods of polluted air. Continuous air quality monitoring is also necessary to achieve better outcomes in the future.

The implications of this study recommend that the government consider setting ambient air PM2.5 standards at levels close to the WHO guideline (< 15 μg/m³), given the significant impact of PM2.5 on human health.

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