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Environmental Health Risk Assessment of Occupational $PM_{2.5}$ and PM_{10} Exposure Among Workers in Home-Based Sanitary Ware Industries in Karangbesuki, Malang City

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Abstract

Introduction: *Home sanitary industries produce particulate matter, posing occupational health risks.* ***Objective:*** *To assess environmental health risks of $PM_{2.5}$ and PM_{10} exposure among 27 sanitary workers in Karangbesuki Village, Malang City using the ARKL approach.* ***Methods:*** *Direct air sampling for $PM_{2.5}$ and PM_{10} concentrations and structured questionnaires for individual exposure parameters were collected to calculate intake and Risk Quotient (RQ).* ***Results and Discussion:*** *Average $PM_{2.5}$ and PM_{10} concentrations ranged from 105.7 to $249.7\ \mu g/m^3$, exceeding ambient standards. Individual intakes were 0.00653--0.02367 mg/kg/day ($PM_{2.5}$) and 0.00693--0.02483 mg/kg/day (PM_{10}). Risk characterization revealed $RQ > 1$ for 96.3% of workers ($n = 26$) for $PM_{2.5}$ and 85.2% ($n = 23$) for PM_{10}. Additionally, 77.8% were smokers and 100% did not use respiratory PPE.* ***Conclusion:*** *Most workers face potential non-carcinogenic health risks, requiring urgent exposure controls and PPE compliance.*

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Introduction

Industrial development contributes to economic growth and employment but may also create occupational and environmental health hazards, including exposure to airborne particulate matter. Workers in home-based industries may be exposed to dust generated during production activities, particularly in workplaces where dust-generating processes are carried out. Home sanitary production involves activities such as grinding, cutting, mixing, and finishing that may generate airborne particulate matter (Sahri et al., 2025; Sentosa et al., 2022).

Particulate matter (PM) is an important air pollutant classified according to aerodynamic diameter into PM_{10} (≤10 µm) and $PM_{2.5}$ (≤2.5 µm). Due to their smaller size, $PM_{2.5}$ particles can penetrate deeper into the lungs, while PM_{10} is mainly deposited in the respiratory tract. Prolonged exposure to particulate matter has been associated with respiratory irritation, reduced lung function, asthma, and other health problems (Fikri et al., 2025; Pertiwi et al., 2024).

The sanitary home industry in Karangbesuki Village, Sukun District, Malang City, is one of the local production centers that uses materials such as cement, sand, decosit or meal, and wire. The production process involves manual and mechanical activities that may generate dust, potentially resulting in occupational exposure to particulate matter. The magnitude of inhalation exposure is influenced by particulate concentration, exposure time and frequency, exposure duration, and individual characteristics such as body weight (Sahri et al., 2025; Sentosa et al., 2022).

Previous studies have reported different levels of health risk associated with particulate exposure.(Regia et al., 2021) found that $PM_{2.5}$ exposure among communities living near cement plants resulted in lifetime and real-time RQ values below one, whereas Putri et al., (2023) reported RQ values above one among sand collectors. These differences indicate that particulate-related health risks may vary according to the exposure source and characteristics of the exposed population. However, evidence regarding $PM_{2.5}$ and PM_{10} exposure among workers in home sanitary industries remains limited. Environmental Health Risk Assessment (EHRA), or Analisis Risiko Kesehatan Lingkungan (ARKL), can be used to estimate individual exposure and characterize potential non-carcinogenic health risks based on intake and Risk Quotient (RQ) level (Ministry of Health of the Republic of Indonesia, 2012)

A preliminary study conducted in April 2026 found that the highest $PM_{2.5}$ and PM_{10} concentrations in the sanitary home industries were 616 µg/m³ and 732 µg/m³, respectively, during grinding activities. These concentrations exceeded the reference values used in this study, namely 55 µg/m³ for $PM_{2.5}$ and 75 µg/m³ for PM_{10}, based on Government Regulation of the Republic of Indonesia No. 22 of 2021. Therefore, this study aimed to assess the environmental health risks associated with $PM_{2.5}$ and PM_{10} exposure among workers in home sanitary industries in Karangbesuki Village, Sukun District, Malang City, using the EHRA approach

Method

This study employed a quantitative descriptive design using the Environmental Health Risk Assessment (EHRA), or Analisis Risiko Kesehatan Lingkungan (ARKL), to assess potential non-carcinogenic health risks associated with occupational exposure to $PM_{2.5}$ and PM_{10} among workers in home sanitary industries. The study was conducted in Karangbesuki Village, Sukun District, Malang City, Indonesia. The study population comprised workers directly involved in the production process, with 27 workers selected using total sampling. Primary data were collected through direct measurements of $PM_{2.5}$ and PM_{10} concentrations and structured questionnaires covering age, body weight, daily exposure time, exposure frequency, exposure duration, smoking status, and PPE use. Workplace temperature and relative humidity were also measured to describe environmental conditions. $PM_{2.5}$ and PM_{10} concentrations were measured using an Air Quality Detector with a direct-reading method, which provides real-time particulate concentration readings. The device was placed in work areas representative of workers' activities and positioned at breathing height. Measurements are taken during the production process, and the $PM_{2.5}$ and PM_{10} concentration results, expressed in µg/m³, are recorded as research data (EPA, 2021).

The measured concentrations were compared with the Indonesian air quality standards stipulated in Government Regulation of the Republic of Indonesia No. 22 of 2021, namely 55 µg/m³ for $PM_{2.5}$ and 75 µg/m³ for PM_{10}. The EHRA assessment followed the stages of hazard identification, dose-response assessment, exposure assessment, and risk characterization (Ministry of Health of the Republic of Indonesia, 2012). Inhalation intake was calculated using the concentration of the risk agent and individual exposure parameters, including inhalation rate, exposure time, exposure frequency, exposure duration, body weight, and averaging time. The intake equation was:

$$\text{Intake} = (C \times IR \times ET \times EF \times ED) / (BW \times AT)$$

Where *C* is the particulate matter concentration, *IR* is inhalation rate, *ET* is exposure time, *EF* is exposure frequency, *ED* is exposure duration, *BW* is body weight, and *AT* is averaging time. The Reference Concentration (RfC) was calculated based on the $PM_{2.5}$ and PM_{10} reference concentrations and exposure parameters according to the ARKL approach. The resulting RfC values were 0.00664 mg/kg/day for $PM_{2.5}$ and 0.00905 mg/kg/day for PM_{10}. Risk characterization was performed using the equation:

$$RQ = \text{Intake} / RfC$$

An $RQ > 1$ was interpreted as indicating a potential non-carcinogenic health risk, whereas $RQ \leq 1$ indicated that the estimated exposure was below the reference level. The risk assessment was conducted for both real-time and lifetime exposure in accordance with the ARKL framework (Ministry of Health of the Republic of Indonesia, 2012). Data were analyzed descriptively using frequencies, percentages, minimum, maximum, and mean values. Exposure characteristics, $PM_{2.5}$ and PM_{10} concentrations, intake, RfC, and RQ were presented in tables and interpreted according to the EHRA framework, Indonesian regulations, and relevant previous studies

Result and Discussion

1. Result

Respondent Characteristics

A total of 27 workers participated in the study. Respondents' age ranged from 26–73 years, while body weight ranged from 45–110 kg. All respondents reported 8 hours/day of exposure and an exposure frequency of 246 days/year. Occupational exposure duration ranged from 3–38 years.

Table 1
Respondent Characteristic

Variable	Category	N	%
Age	26-33	9	33.3
	34-41	4	14.8
	42-49	6	22.2
	50-57	5	18.5
	58-65	1	3.7
	66-73	2	7.4
Body Weight	45-55	5	18.5
	56-66	11	40.7
	67-77	5	18.5
	78-88	3	11.1
	89-99	1	3.7
	100-110	2	7.4
Daily Exposure	8 Hours/Day	27	100
Exposure Frequency	246 days/year	27	100
Exposure Duration	3-8	10	37.0
	9-14	9	33.3
	15-20	1	3.7
	21-26	3	11.1
	27-32	3	11.1
	33-38	1	3.7

$PM_{2.5}$ and PM_{10} Concentrations

Based on Table 2, the average $PM_{2.5}$ concentration at all observation sites ranged from 86.33 to 238 µg/m³. The highest average $PM_{2.5}$ concentration was recorded at Store C at 238 µg/m³, while the lowest concentration was recorded at Store D at 86.33 µg/m³. All average $PM_{2.5}$ concentrations at the observation sites exceeded the ambient air quality standard of 55 µg/m³ as stipulated in Government Regulation No. 22 of 2021. Thus, all monitoring sites showed $PM_{2.5}$ concentrations that did not meet the established quality standards.

Table 2
$PM_{2.5}$ Concentrations at the Observation Sites

Location	9:00 a.m (µg/m³)	11:00 a.m (µg/m³)	2:00 p.m (µg/m³)	Average (µg/m³)	Standard (µg/m³)	Compliance
Store A	155	134	221	510	55	Exceeded
Store B	108	150	114	372	55	Exceeded
Store C	102	99	513	714	55	Exceeded
Store D	28	98	133	259	55	Exceeded
Store E	105	211	278	594	55	Exceeded
Store F	145	169	208	522	55	Exceeded

The average PM_{10} concentrations at the six observation sites ranged from 105.7 to 249.7 μg/m^3. The highest average concentration was recorded at Store C (249.7 μg/m^3), while the lowest was recorded at Store D (105.7 μg/m^3). All observation sites had average PM_{10} concentrations exceeding the Indonesian ambient air quality standard of 75 μg/m^3 stipulated in Government Regulation No. 22 of 2021.

Table 3
PM_{10} Concentrations at the Observation Sites

Location	9:00 a.m (µg/m³)	11:00 a.m (µg/m³)	2:00 p.m (µg/m³)	Average (µg/m³)	Standard (µg/m³)	Compliance
Store A	199	167	288	654	75	Exceeded
Store B	137	186	72	395	75	Exceeded
Store C	135	126	488	749	75	Exceeded
Store D	170	125	175	317	75	Exceeded
Store E	137	189	304	630	75	Exceeded
Store F	121	190	233	544	75	Exceeded

Intake Assessment

Individual $PM_{2.5}$ intake values ranged from 0.00653 to 0.02367 mg/kg/day, while PM_{10} intake values ranged from 0.00693 to 0.02483 mg/kg/day. The variation in intake reflected differences in particulate matter concentration and individual exposure parameters, including body weight, exposure duration, exposure time, and averaging time.

Table 4
Estimated Intake of $PM_{2.5}$

	Variable	Value		Variable	Value
$PM_{2.5}$	Minimum Intake	0.00653 mg/kg/day	**PM_{10}**	Minimum Intake	0.00693 mg/kg/day
	Maximum Intake	0.02367 mg/kg/day		Maximum Intake	0.02483 mg/kg/day

Reference Concentration (RfC)

The calculated RfC values were 0.00664 mg/kg/day for $PM_{2.5}$ and 0.00905 mg/kg/day for PM_{10}.

Risk Characterization

For $PM_{2.5}$, 26 respondents (96.3%) had $RQ > 1$ and 1 (3.7%) had $RQ \leq 1$. For PM_{10}, 23 respondents (85.2%) had $RQ > 1$ and 4 (14.8%) had $RQ \leq 1$. These findings suggest that the vast majority of the study population may experience non-carcinogenic health risks associated with long-term occupational exposure to particulate matter.

Table 5
Distribution of Risk Quotient (RQ)

Parameter	RQ > 1 N (%)	RQ ≤ 1 n (%)
PM 2.5	26 (96.3)	1 (3.7)
PM 10	23 (85.2)	4 (14.8)

Individual and Occupational Factors

All respondents (100%) reported not using respiratory PPE. Among the respondents, 21 (77.8%) were smokers and 6 (22.2%) were non-smokers. Among smokers, 61.9% had a smoking duration of >10 years and reported smoking 11–15 cigarettes/day.

Table 6
Individual and Occupational Factors

Variable	Category	N	%
Use Of Respiratory PPE	Yes	0	0
	No	27	100
Smoking Status	Smoker	21	77.8
	Non-Smoker	6	22.2
Smoking duration (years)	1-5	3	14.3
	6-10	5	23.8
	>10	13	61.9
Number of cigarettes smoked per day (cigarettes/day)	1-5	1	4.8
	6-10	4	19.0
	11-15	13	61.9
	>15	3	14.3

2. Discussion

Respondent Characteristic

Based on table 1 responded Characteristic the age distribution of the 27 respondents varied across the observed groups. The largest proportion of respondents was in the 26–33-year age group (9 respondents; 33.3%), followed by the 42–49-year group (6 respondents; 22.2%) and the 50–57-year group (5 respondents; 18.5%). Meanwhile, the smallest proportion was observed in the 58–65-year group (1 respondent; 3.7%). Age is an important individual characteristic in occupational particulate exposure because physiological changes associated with increasing age may affect respiratory function and an individual's susceptibility to respiratory disorders. Research among workers exposed to dust has shown that increasing age may be associated with reduced lung function, making age an important factor to consider when interpreting the potential health effects of occupational particulate exposure (Maradjabessy et al., 2021).

The respondents' body weight was distributed across the 45–55 kg to 100–110 kg categories, with the largest proportion in the 56–66 kg category (11 respondents; 40.7%). Body weight is an important parameter in the Environmental Health Risk Assessment (EHRA/ARKL) because it is used as the denominator in calculating the inhalation intake of a risk agent. Consequently, when other exposure parameters are the same, individuals with lower body weight may have a greater estimated intake per unit of body weight than individuals with higher body weight. Variation in body weight among respondents may therefore contribute to differences in individual $PM_{2.5}$ and PM_{10} intake (Guidelines for Environmental Health Risk Analysis (EHRA) of the Directorate General of Public Health and D`isease Control, Ministry of Health of the Republic of Indonesia, 2012).

All respondents had the same daily exposure time of 8 hours/day. This indicates that the workers generally had a similar daily working schedule in the home sanitary industry. Exposure time is an important parameter in ARKL because it represents the duration of contact between workers and the risk agent during each working day. A longer exposure time provides greater opportunity for inhalation of airborne particulate matter. However, because all respondents in this study had the same exposure time, this parameter did not contribute to differences in individual intake among respondents

(Guidelines for Environmental Health Risk Analysis (ARKL) of the Directorate General of Public Health and Disease Control, Ministry of Health of the Republic of Indonesia, 2012).

The exposure frequency was also uniform among respondents, at 246 days/year. The same exposure frequency indicates that workers had relatively similar annual work schedules. In the ARKL approach, exposure frequency represents how often an individual is exposed to a risk agent within one year and is incorporated into the calculation of intake. Because the exposure frequency was identical for all respondents, variation in $PM_{2.5}$ and PM_{10} intake was not attributable to differences in exposure frequency, but rather to other parameters such as particulate concentration, body weight, exposure duration, and averaging time (Guidelines for Environmental Health Risk Analysis (ARKL) of the Directorate General of Public Health and Disease Control, Ministry of Health of the Republic of Indonesia, 2012).

The duration of occupational exposure varied considerably, with the largest proportion of respondents having an exposure duration of 3–8 years (10 respondents; 37.0%), followed by 9–14 years (9 respondents; 33.3%). The smallest proportions were found in the 15–20-year and 33–38-year categories, each consisting of 1 respondent (3.7%). Differences in exposure duration indicate that workers had different lengths of occupational contact with particulate matter generated during the production process. Exposure duration is an important parameter in ARKL because longer exposure periods increase the cumulative opportunity for exposure and are incorporated into the calculation of individual intake. Fikri et al., (2025) reported that workers with longer exposure durations tended to have higher particulate matter intake, although intake was also influenced by particulate concentration, body weight, and exposure frequency.

Overall, the characteristics of respondents showed variation in age, body weight, and exposure duration, while daily exposure time and exposure frequency were uniform among respondents. These differences are important in interpreting individual exposure because the ARKL approach combines environmental concentration with individual exposure parameters to estimate the amount of risk agent entering the body. Therefore, although workers were exposed within the same occupational setting, their estimated $PM_{2.5}$ and PM_{10} intake could differ according to their individual characteristics and exposure histories (Fikri et al., 2025; Guidelines for Environmental Health Risk Analysis (ARKL) of the Directorate General of Public Health and Disease Control, Ministry of Health of the Republic of Indonesia, 2012).

PM2.5 and PM10

The average $PM_{2.5}$ concentrations at all observation sites exceeded the Indonesian ambient air quality standard of 55 µg/m³, ranging from 105.7 to 249.7 µg/m³. The highest concentration was recorded at Store C (249.7 µg/m³), while the lowest was at Store D (105.7 µg/m³). This condition indicates that workers were exposed to $PM_{2.5}$ concentrations above the applicable standard, potentially related to dust-generating activities during sanitary production, particularly material processing and finishing (Sahri et al., 2025; Sentosa et al., 2022). The high $PM_{2.5}$ concentrations are concerning because fine particles can penetrate deeply into the respiratory tract and reach the alveolar region, potentially contributing to respiratory irritation and impaired lung function when exposure occurs continuously. These concentrations were subsequently used as exposure parameters in the ARKL calculation to estimate individual $PM_{2.5}$ intake and determine the Risk Quotient (RQ), together with exposure duration, exposure frequency, exposure time, and body weight (Ministry of Health of the Republic of Indonesia, 2012)

The average PM_{10} concentrations at all observation sites also exceeded the Indonesian ambient air quality standard of 75 µg/m³, ranging from 105.7 to 249.7 µg/m³. The highest concentration was recorded at Store C (249.7 µg/m³), while the lowest was at Store D (105.7 µg/m³). The high concentrations may be related to dust-generating activities during sanitary production, particularly material processing and finishing (Sahri et al., 2025; Sentosa et al., 2022). PM_{10} particles can enter the upper respiratory tract and contribute to respiratory irritation and impaired lung function when exposure occurs continuously. Therefore, the elevated PM_{10} concentrations observed in this study indicate potential occupational exposure that requires attention (Pertiwi et al., 2024). The PM_{10} concentrations were subsequently used in the ARKL calculation to estimate individual intake and determine the Risk Quotient (RQ), together with exposure time, exposure frequency, exposure duration, and body weight (Ministry of Health of the Republic of Indonesia, 2012).

Intake Assessment

The $PM_{2.5}$ intake values ranged from 0.00653 to 0.02367 mg/kg/day, while the PM_{10} intake values ranged from 0.00693 to 0.02483 mg/kg/day. The variation in individual intake indicates that workers received different estimated doses of particulate matter despite working in the same type of industry. This variation is influenced by differences in particulate matter concentration and individual exposure parameters, particularly body weight, exposure duration, exposure time, and averaging time. In the ARKL approach, these parameters are combined to estimate the amount of pollutant entering the body (Guidelines for Environmental Health Risk Analysis (ARKL) of the Directorate General of Public Health and Disease Control, Ministry of Health of the Republic of Indonesia Kesehatan, 2012).

Body weight can affect intake because it is used as the denominator in the inhalation intake equation. With other parameters being equal, workers with lower body weight may have higher intake values per unit body weight. Therefore, differences in body weight among respondents may contribute to variation in the estimated $PM_{2.5}$ and PM_{10} intake. The intake results were subsequently used to characterize the non-carcinogenic health risk through the Risk Quotient (RQ). An intake value alone does not determine whether workers are at risk; it must be compared with the corresponding Reference Concentration (RfC). An $RQ > 1$ indicates a potential non-carcinogenic health risk, whereas $RQ \leq 1$ indicates that the estimated exposure is below the reference level (Ministry of Health of the Republic of Indonesia, 2012)

Risk Characterization

The risk characterization showed that 96.3% of respondents exposed to $PM_{2.5}$ had $RQ > 1$ (26 respondents), while 3.7% had $RQ \leq 1$ (1 respondent). This indicates that the vast majority of the workers had a potential non-carcinogenic health risk from $PM_{2.5}$ exposure. The high proportion of respondents with $RQ > 1$ is consistent with the elevated $PM_{2.5}$ concentrations measured at all observation sites, which exceeded the applicable standard. According to the ARKL approach, an $RQ > 1$ indicates that the estimated exposure exceeds the reference concentration and therefore requires risk management (Guidelines for Environmental Health Risk Analysis (ARKL) of the Directorate General of Public Health and Disease Control, Ministry of Health of the Republic of Indonesia, 2012)

For PM_{10}, 85.2% of respondents had RQ > 1 (23 respondents), while 14.8% had RQ ≤ 1 (4 respondents). Although the proportion was slightly lower than that of $PM_{2.5}$, the majority of the respondents were still categorized as having potential non-carcinogenic health risks. This finding is consistent with the elevated PM_{10} concentrations observed at the study locations. Differences in RQ between respondents may be influenced by individual exposure parameters, including body weight, exposure duration, and averaging time, which affect the estimated intake (Ministry of Health of the Republic of Indonesia, 2012).

Overall, the high proportion of respondents with RQ > 1 for both $PM_{2.5}$ and PM_{10} indicates that occupational particulate exposure in the home sanitary industry requires serious attention. Previous research has also demonstrated that particulate exposure can produce different levels of health risk depending on exposure concentration and characteristics of the exposed population (Putri et al., 2023; Regia et al., 2021). Therefore, exposure-control measures are urgently needed to reduce workers' exposure to $PM_{2.5}$ and PM_{10} and prevent the potential health risks associated with prolonged occupational exposure.

Individual and Occupational Factors

Most respondents were smokers (21 respondents; 77.8%), with 61.9% reporting a smoking duration of >10 years. In terms of daily cigarette consumption, the largest proportion smoked 11–15 cigarettes/day (61.9%). Smoking is an important individual factor to consider when interpreting respiratory health risks because tobacco smoke can contribute to respiratory impairment and may act together with occupational particulate exposure. Previous research has reported that smoking can be associated with reduced lung function among workers exposed to occupational dust (Abidin et al., 2021; Chaeruddin et al., 2021).

All respondents (27; 100%) reported that they did not use respiratory PPE during work. The absence of respiratory protection may increase workers' direct exposure to airborne particulate matter generated during production activities. Although smoking status and PPE use were not included directly in the $PM_{2.5}$ and PM_{10} intake calculations, both factors are important when interpreting occupational exposure and identifying appropriate measures to reduce workers' exposure to particulate matter.

Conclusion

$PM_{2.5}$ and PM_{10} concentrations in all observed home sanitary industry locations exceeded the applicable Indonesian ambient air quality standards. The average $PM_{2.5}$ and PM_{10} concentrations both ranged from 105.7–249.7 $\mu g/m^3$. Individual $PM_{2.5}$ intake ranged from 0.00653–0.02367 mg/kg/day (and PM_{10} intake ranged from 0.00693–0.02483 mg/kg/day), while the risk characterization showed that 96.3% of respondents had RQ > 1 for $PM_{2.5}$ and 85.2% had RQ > 1 for PM_{10}, indicating potential non-carcinogenic health risks among the vast majority of the workers. In addition, 77.8% of respondents were smokers and 100% did not use respiratory PPE, representing important occupational and behavioral factors that should be considered in exposure control.

Reference

Abidin, A. U., Henita, N., Rahmawati, S., & Maziya, F. B. (2021). Analisis Risiko Kesehatan Paparan Debu Terhadap Fungsi Paru Pada Pekerja Di Home Industry C-Max. *Jurnal Sains Dan Teknologi Lingkungan*, *13*, 34–39. https://doi.org/10.20885/jstl.vol13.iss1.art3

Chaeruddin, A. D. R. D., Abbas, H. H., & Gafur, A. (2021). Analisis risiko kesehatan lingkungan pajanan debu kayu pada pekerja mebel informal di Kelurahan Antang Kecamatan Manggala Kota Makassar. *Window of Public Health Journal*, *2*(2), 322-335. https://doi.org/10.33096/woph.v2i2.154

Epa. (2021). *Air Sensor Performance Testing Protocols, Metrics, And Target Values For Pm2.5 And Ozone*. 1–11.

Fikri, E., Dewi, D. R., & Juariah, L. (2025). Analisis Risiko Kesehatan Lingkungan (ARKL) Pajanan PM2. 5 dan PM10 Pada Pekerja PT. Beton Elemenindo Perkasa Tahun 2024. *Jurnal Kesehatan Lingkungan Indonesia*, *24*(1), 115-122. https://doi.org/10.14710/jkli.67628

Kesehatan, D. J. P. Dan P. K. (2012). *Pedoman Analisis Risiko Kesehatan Lingkungan (Arkl)*.

Maradjabessy, F. A., Yuniarti, & Adji, H. W. (2021). Scoping Review : Efek Debu Terhadap Fungsi Paru Pekerja Scoping Review : Effect Of Dust On Workers ' Lung Function. *Jurnal Integrasi Kesehatan Dan Sains (Jiks)*, *3*(22), 80–85. https://doi.org/10.29313/jiks.v3i1.7358

Pertiwi, K. D., Lestari, I. P., & Afandi, A. (2024). Kesehatan Analisis Risiko Kesehatan Lingkungan Pajanan Debu Pm10 Dan Pm2.5 Pada Relawan Lalu Lintas Di Jalan Diponegoro Ungaran. *Pro Health Jurnal Ilmiah*, *6*(2), 85–91.

Putri, D. Arista, Rosyada, A., Sari, D. M., & Islamiati, D. (2023). Analisis Risiko Kesehatan Lingkungan Terhadap Paparan Debu Pada Pekerja Pasir Di Kota Palembang. *Jurnal Kesehatan Komunitas*, *9*(3), 485–493. 10.25311/keskom.Vol9.Iss3.1428

Regia, R. A., Bachtiar, V. S., & Solihin, R. (2021). Analisis Risiko Kesehatan Akibat Paparan Particulate Matter 2, 5 (PM2, 5) Dalam Rumah Tinggal di Perumahan X Kawasan Industri Semen. *Jurnal Ilmu Lingkungan*, *19*(3), 531-540. https://doi.org/10.14710/Jil.19.3.531-540

Sahri, M., Arini, S. Y., Jannah, F., & Amin, M. (2025). Occupational exposure assessment of fine particulate matter (PM2. 5) and respirable crystalline silica in the ceramic industry of Indonesia. *Atmosphere*, *16*(10), 1125. https://doi.org/10.3390/atmos16101125

Sentosa, E. A., Riviwanto, M., & Seno, B. A. (2022). Analisis Risiko Gangguan Fungsi Paru Akibat Paparan Debu Pm10 Pada Pekerja Mebel Kayu. *Jurnal Sanitasi Lingkungan*, *2*(1), 30–37. https://doi.org/10.36086/jsl.v2i1.1239