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Hematological Profile and Air Quality: A Case Study in Belendung Subdistrict, Benda, Tangerang

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Abstract

Cities with high population density, high traffic volume of public and private transportation, and significant industrial operations in areas surrounding airports constitute a combination that worsens air pollution. Exposure to pollutants could impact the hematological system. This study aims to determine air pollution exposures in Belendung Subdistrict, Benda District, Tangerang. This study served as a preliminary step or pilot study, conducted within a 4.6 km radius of the airport, and located near some industries in the area, using a cross-sectional and purposive method. SO_2, CO, NO_2, Ox as O_3, NMHC, TSP, Pb, $PM_{2.5}$, and PM_{10} levels were measured as air pollution variables. These parameters were assessed on the 3rd and 5th days before blood sampling. Neutrophils, eosinophils, monocytes, basophils, lymphocytes, CRP, leukocytes, hemoglobin, erythrocytes, hematocrit, platelets, MCV, MCH, MCHC, and ESR were measured from 12 male and 12 female respondents. The results showed that the air quality ranged within the standard threshold except for PM_{10}, and most residents have normal biomarkers in their blood. It indicated that PM_{10} merely activates basic immune responses in the body. The observed inflammation provides a correlation between MCH and MCV, with a value of 0.905.

Introduction

Environmental pollution is a global problem that threatens public health and degrades air quality through various industrial, transportation, and human activities that produce hazardous substances (Bevan, *et al.,* 2021). As a major transportation hub, the area around the airport is not only traversed by aircraft but also by thousands of ground vehicles every day, which, together with nearby industries, generate substantial air pollutant emissions. Studies show that transportation systems in densely populated and urbanized Southeast Asian cities significantly contribute to Particulate Matter <2.5 mm ($PM_{2.5}$) and Nitrogen Oxides (NO_X) concentrations (Al Alim *et al.,* 2025). Pollutants produced by airport activities can disperse ten kilometers into residential areas, potentially degrading air quality and public health (Moradi, *et al.,* 2024). Exposure to air pollution (Sulfur Dioxide (SO_2), Photochemical Oxidants (O_3), caused significant changes in the blood, including decreases in red blood cells, hemoglobin, and other erythrocyte parameters (Sepehri *et al.,* 2024). A study involving men aged 22 to 45 years found that exposure to air pollution can significantly increase the number of neutrophils, lymphocytes, and monocytes in blood, and decrease the number of eosinophils

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and basophils (Xue *et al.,* 2023). High exposure to air pollution in urban areas negatively affected blood components, including decreased red blood cells and hemoglobin, as well as increased white blood cells and erythrocyte sedimentation rate, indicating an inflammatory response to gaseous pollutants. The main contributing factors were higher population density, vehicular activity, and industrial emissions area (AL-Shuraifi & Dallalbashi, 2024), worsen morbidity and mortality in various health conditions (Urrutia-Pereira *et al.,* 2022). Long-term exposure to pollution has a significant impact on reducing hemoglobin levels, thereby elevating the risk of anemia in the general population (Hwang & Kim, 2024).

Exposure to $PM_{2.5}$ particulate, black carbon, Carbon Dioxide (CO_2) and Nitrogen Dioxide (NO_2) has been demonstrated to be associated with changes in the distribution of leukocyte subtypes, which directly affect the human immune response (Gao *et al.,* 2019), while PM_{10} particulate affects the reduction of erythrocytes and their membrane shape changes (Orel *et al.,* 2021). The air pollution not only impacts the hematological system but also contributes to metabolic and immunological disorders. This may affect lipid dysfunction, one of which is impaired High-Density Lipoprotein (HDL) function that can reduce antioxidant and anti-inflammatory capacity, also increasing the risk of cardiovascular disease through systemic inflammatory mechanisms and oxidative stress (Yi. Li *et al.,* 2024).

Activities in airport areas, such as aircraft movements, vehicle traffic, and nearby industrial operations, are the main sources of air pollutant emissions (Passarella & Veny, 2023). Therefore, it is necessary to conduct a study related to the measurement of pollutant levels in residential areas located 4.6 km from the Airport, along with a pilot study of the hematological profiles of the surrounding population. This study aims to determine the correlation between air pollution exposures in residential areas through the examination of hematologic profiles and complete blood counts of residents aged 25 to 35 years. Furthermore, the present study is anticipated to provide recommendations regarding solutions to air pollution problems in residential areas. Belendung Subdistrict wasselected as the study area. It is also located in industrial areas, with high traffic volume and densely populated areas, making it an appropriate area to illustrate air pollution exposure derived from airport activities, transportation, and industrial operations. This study area was further designated for a pilot study because its characteristics facilitate representative data collection to support recommendations regarding air quality issues within the subdistrict.

Method

This study has obtained ethical approval from the Research Ethics Commission of Universitas Islam Negeri Syarif Hidayatullah Jakarta, with the ethics approval letter number Un.01/F.10/KP.01.1/KE.SP/07.08.024/2025 on July 30, 2025. This study employed a cross-sectional method with 24 respondents (12 male and 12 female) as a pilot study residing within a 4.6 kilometers radius of the airport, specifically in RT 03 RW 02, Belendung Village, Benda District, Tangerang City (Figure 1). The respondents were selected using purposive sampling with an age range from 25 to 35 years, non-smokers, and good health conditions. Participants were considered to be in good condition by the doctor if they were physically healthy, free from active infectious diseases, were not pregnant or breastfeeding (if applicable), were not taking medications that could affect the study parameters, and had normal blood pressure.

Air quality measurements are conducted at RT 03 RW 02, Belendung Village, Benda District, Tangerang City (S 6^o 8' 53,142" E 106^o 40' 11,172"). The observed parameters consist of SO_2, Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Photochemical Oxidants (Ox) as Ozone (O_3), Non-Methane Hydrocarbons (NMHC), dust particles (<100 mm (Total Suspended Particulate (TSP)), Particulate Matter <10 mm (PM_{10}), $PM_{2.5}$) and Lead (Pb). The observation was conducted twice on August 5-6, 2025, and August 7-8, 2025, were carried out on the 5th and 3rd days before residents' blood sampling at the same location (Index, 2025). It started at 09:00 Western Indonesian Time (WIB; UTC+7). The observation data obtained were subsequently compared with air

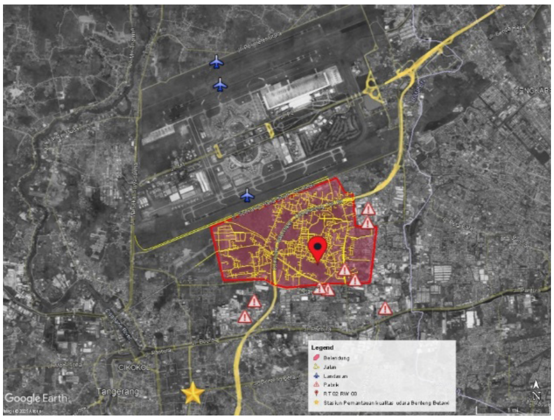

FIGURE 1. Location of Blood Sampling and Air Quality Measurement.

quality data from Real-time Air Quality (AQI) at the sampling point of Tangerang Benteng Betawi, Tanah Tinggi, Indonesia, available at: https://aqicn.org/station/@515938/.

SO_2 was measured using the method from Standar Nasional Indonesia (SNI) 7119.7:2017 for 24 hours, CO measured using UP.IK.21.01.250 (Continuous Active Electrochemical) method for 1 hour, NO_2 measured using SNI 7119.2:2017 method for 24 hours, Ox as O_3 measured using SNI 7119.8:2017 method for 1 hour, NMHC measured using SNI 7119.13-2009 for 3 hours, TSP measured using SNI 7119.3:2017 method for 24 hours, PM_{10} measured using SNI 7119.15:2016 method for 24 hours, $PM_{2,5}$ measured using SNI 7119.14:2016 for 24 hours, and Pb measured using UP.IK.21.01.212 (ICP) for 24 hours. The data were collected in accordance with Government Regulation (PP) No. 22/2021 of Indonesia concerning National Ambient Air Quality Standards..

An interview-based survey and 5 mL of blood samples were collected from respondents. The laboratory analysis complete blood counts were conducted to determine leukocyte differentiation levels (neutrophils, eosinophils, monocytes, basophils, and lymphocytes) and C-reactive protein (CRP); hematology (total leukocytes, hemoglobin, erythrocytes, hematocrit, and platelets); Mean Corpuscular (MC) values (Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), and Mean Corpuscular Hemoglobin Concentration (MCHC); and Erythrocyte Sedimentation Rate (ESR). Leukocyte differentiation, complete hematology, and MC values were measured with a hematology analyzer; CRP was measured using the Immunofluorescence Assay (IFA) method; and ESR was measured using the Westergren method. Furthermore, interviews with participating volunteers were conducted, including questions related to general health conditions, daily activity patterns, and air exposures, lifestyle and habits. The collected data was statistically analyzed using the Orange Data Mining platform to examine the correlation between variables using the Pearson Correlation method.

Result and Discussion

High density of vehicular and industrial emissions in urban high-density areas worsens air quality and increases public health risks (Reche *et al.,* 2022). This condition can also be observed in Indonesia's rapidly developing urban areas with high transportation activity, including Belendung Subdistrict, Benda District, Tangerang City. The combination of dense population, heavy traffic flow, and nearby industrial activity makes Belendung one of the areas vulnerable to deteriorating air quality. The results indicate that the air quality remains within threshold limits. The measured values of SO_2, CO, NO_2, O_x as O_3, NMHC, TSP, Pb, $PM_{2.5}$,

Table 1. Ambient Air Measurement Data

Indicator	Sampling Time	Standard Threshold	Unit	Result (1)	Result (2)
SO_2	24 hours	75	μg/m^3	27	30
CO	1 hour	10,000	μg/m^3	3,517	3,654
NO_2	24 hours	65	μg/m^3	24	26
O_X as Ozone (O_3)	1 hour	150	μg/m^3	41	42
NMHC	3 hours	160	μg/m^3	11	13
TSP (<100 mm)	24 hours	230	μg/m^3	34	41
PM_{10} (<10 mm)	24 hours	75	μg/m^3	14	18
$PM_{2.5}$ (<2.5 mm)	24 hours	55	μg/m^3	9	12
Pb	24 hours	2	μg/m^3	0.02	0.03

* Result (1): August 5-6, 2025 and Result (2): August 7-8, 2025

and PM_{10} are normal or within the standard threshold (Table 1).

Directly collected field data were then compared with data from AQI (Index, 2025) at the nearest air monitoring point, which was approximately 3 to 4 km from Belendung Subdistrict, Benda District, Tangerang City. The direct measurement results of PM_{10} are normal on the second day of observation (August 7-8, 2025), compared with data from AQI that exceeded the standard threshold, namely 83.6 μg/Nm^3 and 88.3 μg/Nm^3, which means abnormal. This situation could be caused by local rain only in the study area. Other ambient air parameters (SO_2, CO, NO_2, O_3, NMHC, TSP, $PM_{2.5}$, and Pb) showed normal results, although several of them indicated moderate values in the AQI data.

The discrepancy between the field data and the AQI is presumed to result from 3 hours out of 24 hours of rainfall in the first ambient air measurement. In the second measurement, rainfall was recorded again for approximately 3 to 4 hours out of 24 hours. It may also be caused by ambient air measurement in different sampling points, as the AQI data was obtained from the closest station point to Benda District, namely the Tangerang Benteng Betawi AQIStation, Tanah Tinggi. Based on the interview results related to respondents' health conditions and lifestyle, the majority of respondents were found not to have any chronic diseases. Furthermore,

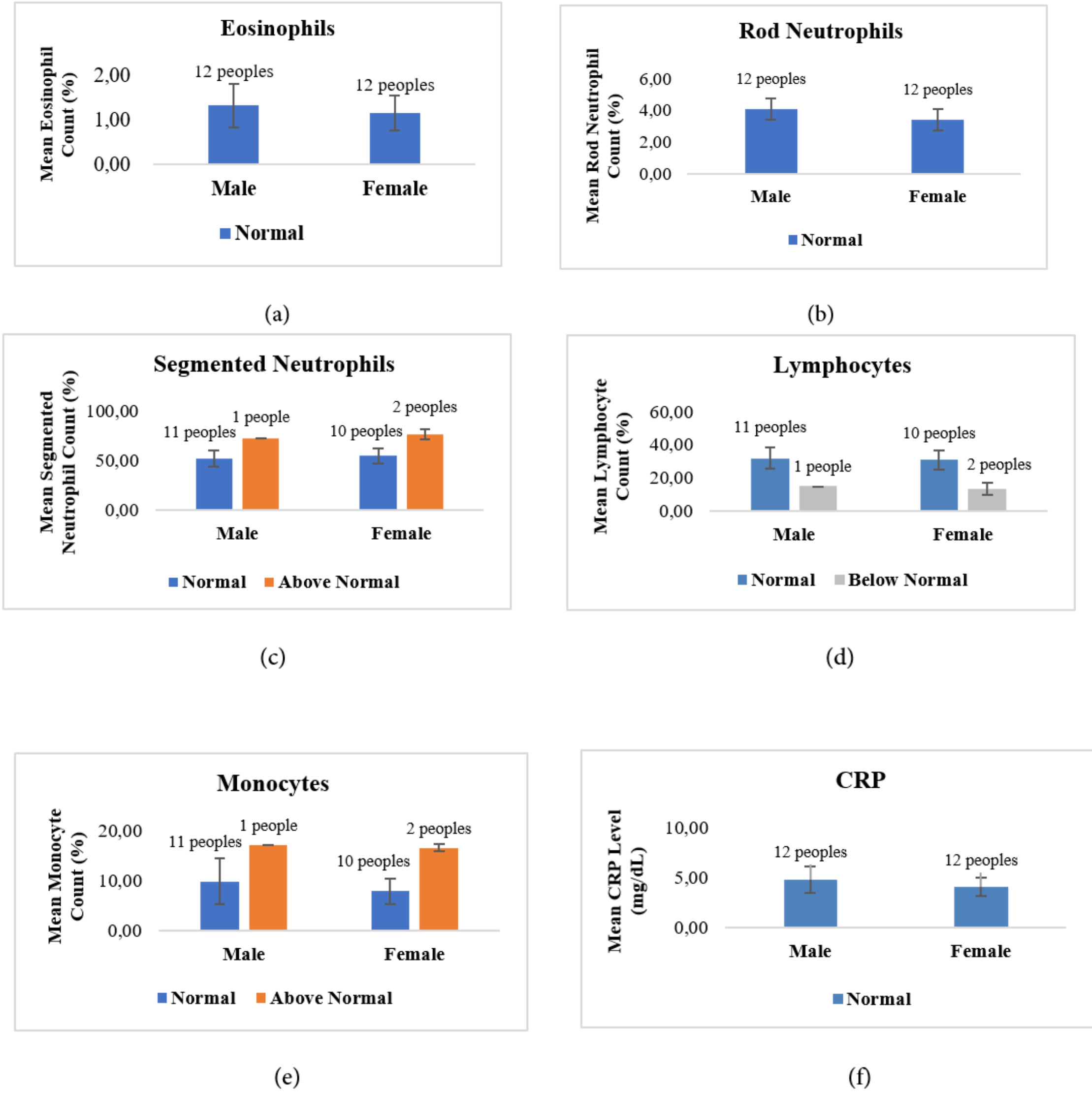

Figure 2. Mean of Leukocyte Differentiation According to the Gender (a) Eosinophils, (b) Rod Neutrophils, (c) Segmented Neutrophils, (d) Lymphocytes, (e) Monocytes, (f) CRP.

the respondents tend to spend time outdoors. Figure 2 presents the mean differences in each leukocyte differentiation observation consisting of eosinophils, rod neutrophils, segmented neutrophils, lymphocytes, monocytes, and CRP.

Basophils were absent (0%) in both males and females; however, this remains within normal limits. Eosinophils in male and female subjects were within reference limits, with an average of 1.33% and 1.17%, respectively. The same pattern was also detected in rod neutrophils, with an average of 4.08% in males and 3.42% in females. The mean value of segmented neutrophils was found to exceed normal limits in two female individuals (76.5%) and one male individual (72%). Subsequently, one male and two females had lymphocytes below reference values with an average of 15% and 13.5%, respectively. Monocytes above normal exhibited a mean value of 17% in males and 16.5% in females. However, the CRP in all male and female subjects was within normal limits, with mean values of 4.80 mg/dL and 4.08 mg/dL.

The mean basophil and eosinophil count in male and female participants was within normal limits. This condition indicates that the exposure to air pollution did not trigger a significant allergic response, likewise in

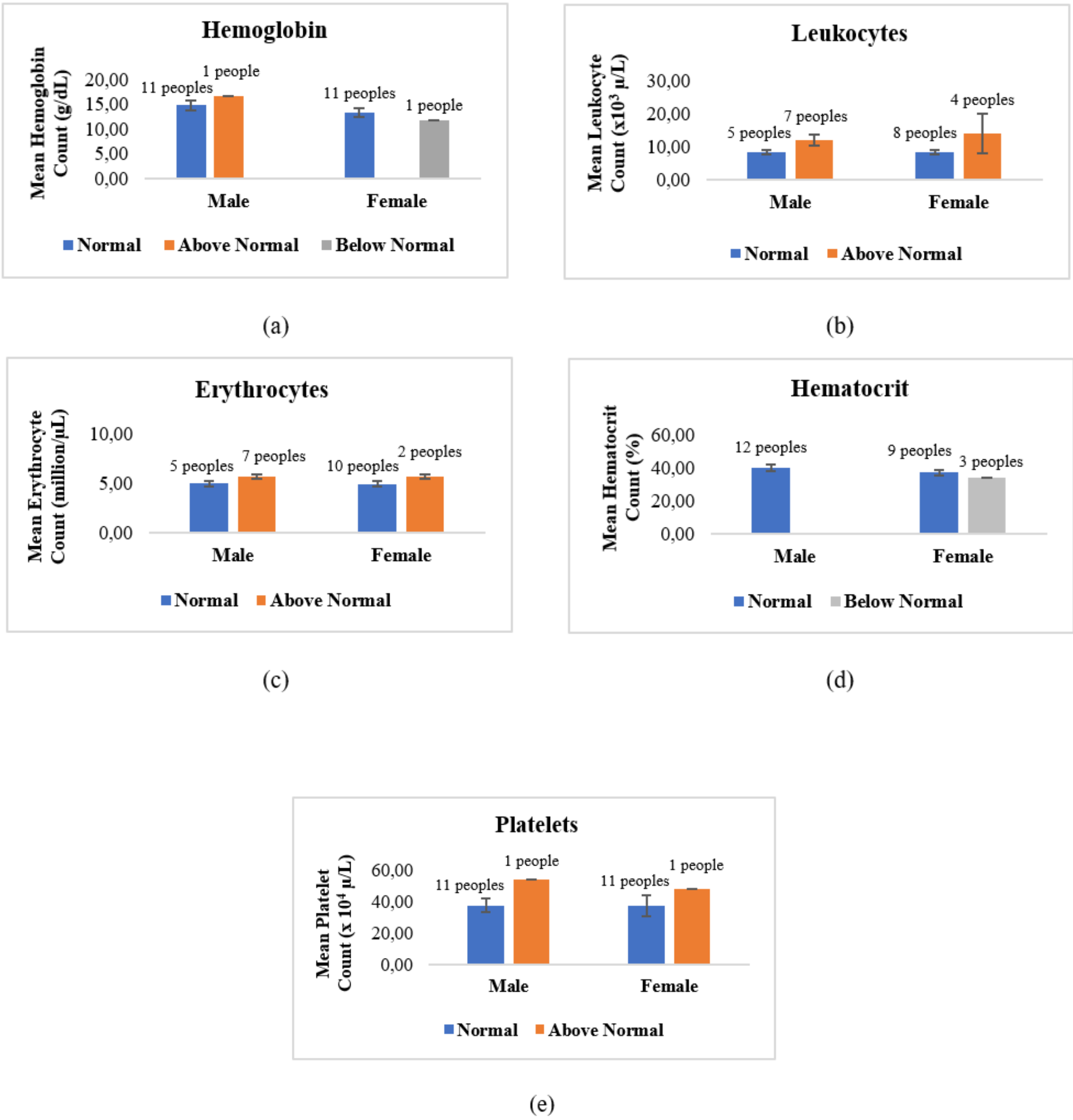

Figure 3. Mean of Hematology Parameter According to the Gender (a) Hemoglobin, (b) Leukocytes, (c) Erythrocytes, (d) Hematocrit, (e) Platelets.

basophils. Air pollution dominantly stimulates innate immune cells such as neutrophils compared to eosinophils (Volder *et al.,* 2025). Rod neutrophils were found slightly higher in male participants than in females; however, this remains within the normal ranges, considering a mild activation of the immune system as a result of chronic exposure to pollutants (Gałuszka-Bulaga *et al.,* 2023).

A small proportion of subjects experienced an increase in segmented neutrophils (one male and two female individuals), reflecting chronic inflammation; this condition is aligned with the findings that long-term exposure to $PM_{2.5}$ could elevate mature neutrophil count and inflammation cytokines (Liu *et al.,* 2024). Several subjects showed a reduction in lymphocyte count (one male and two female individuals). This reduction may indicate mild immunosuppression, while chronic pollution could induce lymphocyte apoptosis. An increase in monocytes above normal in a subset of subjects indicates immune activation (Marín-Palma *et al.,* 2023).

The CRP values are approaching the upper limit of normal, indicating low-grade systemic inflammation. A study by Kim et al. 2022 found a strong correlation between long-term exposure to pollutants and elevation of CRP serum (Kim *et al.,* 2022). Hematology examination results indicate that leukocyte counts in some residents are elevated above normal levels. The increase in leukocyte counts indicates an inflammatory response due to air pollution exposure, which is in line with findings that chronic exposures to $PM_{2.5}$ can increase the number of peripheral leukocytes through the activation of inflammatory pathways (Aretz *et al.,* 2024). The observation results of the hematology parameter, which consisted of hemoglobin, leukocytes, erythrocytes, hematocrit, and platelets, are presented in

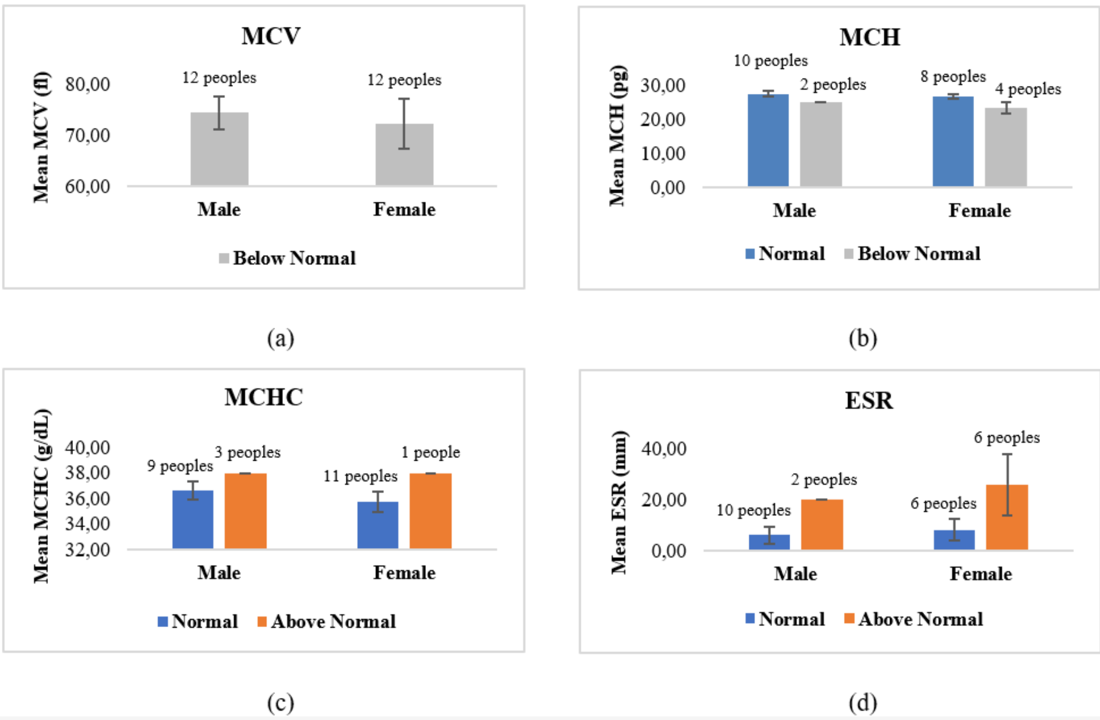

Figure 4. Mean of Mean of MC Value Parameter According to the Gender (a) MCV, (b) MCH, (c) MCHC, (d) ESR.

Figure 3. Despite the presence of one male individual with hemoglobin above normal (±16.8 g/dL) and one female individual below normal (±11.7 g/dL), most hemoglobin counts in participants remained within normal limits. The Leukocyte count in some participants was above normal, with a mean of 12×10^3 μ/L in seven males and 14×10^3 μ/L in four females, in comparison with normal group (8.3×10^3 μ/L).

The erythrocyte levels in seven male and two female individuals were above normal, with a mean of 5.69 million/μL and 5.65 million/μL, respectively. The average normal erythrocyte count in females was 4.92 million μ/L and 4.98 million μ/L in males. According to the hematocrit measurement, it was found that three female individuals were below-normal levels (34%), while the entire male group presented normal levels (40.25%). The number of male and female individuals with a normal platelet count was similar. Namely, there was only one individual from each group with a mean of 53.80×10^4 μ/L and 47.80×10^4 μ/L.

Most participants had hemoglobin levels within the normal range, although one participant from the female group had a subnormal hemoglobin level, and above normal for the male group. This variation could be linked to the pollutant exposure, which affects hemoglobin formation. Previous studies have shown a decline in hemoglobin associated with one- to two-year exposure to PM_{10}, SO_2, and CO pollutants, and annual PM_{10} exposure is correlated with anemia (Hwang & Kim, 2024). A subset of participants experienced erythrocyte elevation, particularly in males (±5.69 million/μL in 7 individuals) compared to the normal group (±4.98 million/μL), which may result from tissue hypoxia due to carbon monoxide exposure (Osborne *et al.,* 2023).

The majority of male (12 individuals) and female participants (9 individuals) had normal haematocrit levels, although a few (3 female individuals) showed subnormal levels, which indicates anaemia, resulting in a compromised immune response against pathogens. $PM_{2.5}$ and PM_{10} exposure may result in oxidative stress and suppress erythrocyte production (Asplund *et al.,* 2024). This study revealed a high level of platelets in one male and female participant; this is associated with inflammation due to air pollution exposure. Studies have shown that prolonged exposure to particulates is associated with increased platelet activation and coagulation (Hantrakool *et al.,* 2024).

Figure 4 presents observation results for the MC value parameters, including MCV, MCH, MCHC, and ESR. It was observed that MCV levels in all male and female groups were found to be subnormal, with an average of 74.42 fL and 72.17 fL, respectively. Four females and two males had MCH levels lower than normal, with an average of ±23.25 pg and ±25 pg. The average MCH in the normal range among male participants was 27.5 pg and 26.63 pg in female participants. Three male and one female participant were found to have MCHC levels above normal, with an average of 38 g/dL. The mean of normal MCHC levels was found in male participants at 36.67 g/dL and 35.73 g/dL in female participants. According to the results, six females and two males had elevated ESR levels, with an average of ±25.83 mm and ±20 mm. Additionally, the average of normal ESR was recorded as ±8.17 mm in females and ±6.10 mm in males.

All participants had experienced a decrease in MCV level; some participants showed a decrease in MCH and an increase in MCHC. A decrease in MCV and MCH is

TABLE 2. Pearson Correlation Between Immune Response Variable

No.	Variables	Correlation (+)	Correlation (-)
1	MCH : MCV	+0.905	
2	ESR : Leucocytes	+0.647	
3	Lymphocytes : segmented neutrophils		-0.923

potentially indicative of microcytic anemia due to chronic inflammation. Studies have reported that exposure to air pollution can interfere with iron metabolism, which affects the size and hemoglobin levels of erythrocytes (He *et al.,* 2023). The increase in ESR level was observed in two male and six female participants; this finding indicates non-specific inflammation, and the increase suggests chronic inflammation (Ramien *et al.,* 2024).

The low MCV indicates that erythrocyte cells are smaller than normal (microcytosis), commonly associated with iron deficiency (Aksu & Ünal, 2023). This condition reduces oxygen transport capacity; therefore, the immune cells (neutrophils and lymphocytes) did not receive optimal energy levels for proliferation and phagocytosis, resulting in a weakened immune system (Rogers *et al.,* 2024). Air pollution exposure (i.e., $PM_{2.5}$, PM_{10}, NO_2, and CO) has worsened this condition through oxidative stress, systemic inflammation, and erythropoiesis (Liu *et al.,* 2022). This study finds that long-term exposure to pollutants can increase the risk of iron deficiency (anemia), which is closely associated with low levels of MCV (Hwang & Kim, 2024). The Pearson correlation analysis in Table 2 showed a strong correlation across several hematology parameters. The MCH variable had a strong positive correlation with MCV ($r = +0.905$) and also between ESR and leucocytes ($r = +0.647$). However, lymphocytes had a weak correlation with segmented neutrophils ($r = -0.923$).

The studies observed that the increase in MCV is generally followed by an increase in MCH. In physiological terms, red blood cells with larger sizes (high MCV) have a larger capacity to accommodate hemoglobin; therefore, the MCV level also increased (D. Li *et al.,* 2024). A different study by Zhang et al. 2021 demonstrated that MCV and MCH levels had a non-linear relationship with all-cause mortality risk and cardiovascular mortality (Zhang *et al.,* 2021). Furthermore, the relationship between leukocytes and ESR indicated that an increase in the number of leukocytes is aligned with an ESR value, which physiologically reflects systemic inflammation response among individuals exposed to environmental pollutants. These findings correspond with a study in Mosul–Al-Sheikhan, which indicated that groups with higher ESR values had an increased number of leukocytes as an inflammatory process, due to environmental factors (AL-Shuraifi & Dallalbashi, 2024). Other studies also revealed that SO_2, NO_2, and $PM_{2.5}$ exposure contributed to the increase in leukocytes (Lee & Yoon, 2024).

Meanwhile, an increase in ESR values is often associated with tissue damage and oxidative stress caused by air contaminants (AL-Shuraifi & Dallalbashi, 2024). Therefore, the positive correlation between these two variables is indicated as a non-specific indicator of inflammation to air pollution. Both variables showed a directional trend as a biological response to oxidative stress and respiratory tract infection resulting from polluted environmental conditions.

The relationship between lymphocytes and segmented neutrophils indicates a balanced immune system, where an increase in lymphocytes is followed by a reduction in segmented neutrophils, and vice versa. It reflects a compensatory mechanism between leucocyte components. A study by Sukrisman et al. 2021 finds that the Neutrophil-to-Lymphocyte Ratio (NLR) is often used as a marker of balance between innate and adaptive immune systems in addition to reflecting the level of inflammatory load (Sukrisman *et al.,* 2021).

Another study in Henan, China, with 5,816 participants showing that exposure to air pollution ($PM_{2.5}$, PM_{10}, NO_2, SO_2, CO, O_3) has a negative correlation to lymphocytes and positively correlates with neutrophils. Higher concentrations of pollution tend to decrease the level of lymphocytes and increase neutrophils, indicating the body's response to pollution exposure due to oxidative stress (Yavorkovsky, 2021). The study findings showed that air pollution did not significantly impact the immune response in residents aged 25 to 35. However, a basic immune response activation triggered oxidative stress and inflammation, which reduced the MCV count in all respondents. Furthermore, a decrease in MCV level can also trigger the risk of hematological disorders such as anemia.

Conclusion

Exposure to air pollution in residential areas in Belendung Subdistrict, Benda District, Tangerang did not show any effect on several hematological profiles of residents aged 25 to 35 years. The study showed that exposure to $PM_{2.5}$, PM_{10}, NO_2, and CO pollutants is associated with an increased risk of reduced hematology components, one of which is anemia. The observed inflammatory response is associated with substandard MCV values in 12 male and 12 female volunteers, indicating a strong correlation between MCH and MCV, with a coefficient of 0.905. According to the result of the study, the proposed recommendation is implementing an intensive greening program and providing education about health and nutrition.

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