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ORIGINAL ARTICLE

Air Pollution and the Risk of Acute Ear, Nose, and Throat Diseases: A Cross-Sectional Study in West Jakarta

Polusi Udara dan Risiko Penyakit Akut pada Telinga, Hidung, dan Tenggorok: Studi Cross-Sectional di Jakarta Barat

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ABSTRACT

Background

Air pollution, particularly in urban areas such as West Jakarta, is a major public health concern. Long-term exposure to pollutants, including particulate matter (PM) 2.5, can lead to respiratory problems, including acute otolaryngologic diseases. Outdoor workers, such as those involved in urban infrastructure maintenance, are more vulnerable to these conditions. This study aimed to assess the relationship among air pollution levels, mucociliary clearance function, and the prevalence of acute otolaryngologic diseases among outdoor workers in West Jakarta.

Methods

A cross-sectional study was conducted among 120 Public Infrastructure and Facility Maintenance (PPSU) workers in the Cengkareng, Rawa Buaya, and Cengkareng Timur sub-districts. Air quality was assessed using data from nearby monitoring stations, measuring PM2.5 levels and the Air Quality Index (AQI). Health assessments included anamnesis, patient-reported outcome questionnaires, saccharin transit test, and otorhinolaryngologic endoscopic assessments.

Results

The average PM2.5 level was 57.58 µg/m³ (high risk for respiratory issues), and the AQI was 144.71 µg/m³ (unhealthy). The saccharin transit time test averaged 427.29 seconds, with a mean nasal floor length of 63.76 mm. The prevalence of acute rhinopharyngitis was 59.2%, rhinosinusitis 8.3%, occupational rhinitis 9.2%, and vitamin D insufficiency 67.5%. However, no significant correlation was found between air pollution exposure, mucociliary function, and acute otolaryngologic diseases ($p > 0.05$).

Conclusions

Despite high exposure to air pollution, no significant relationship was observed between air pollution, mucociliary clearance, and acute otolaryngologic diseases among PPSU workers. Further studies with larger sample sizes and longitudinal designs are needed.

Keywords: Air pollution; Acute otolaryngologic diseases; Mucociliary clearance; Saccharin transit time test; Outdoor workers; PM2.5.

ABSTRAK

Latar Belakang

Polusi udara, terutama di daerah perkotaan seperti Jakarta Barat, merupakan masalah kesehatan masyarakat yang serius. Paparan jangka panjang terhadap polutan seperti materi partikulat (PM) 2.5 dapat menyebabkan gangguan pernapasan, termasuk penyakit otolaringologis akut. Pekerja luar ruangan, seperti mereka yang terlibat dalam pemeliharaan infrastruktur kota, lebih rentan terhadap kondisi tersebut. Penelitian ini bertujuan untuk menilai hubungan antara tingkat polusi udara, fungsi pembersihan mukosilia, dan prevalensi penyakit otolaringologis akut pada pekerja luar ruangan di Jakarta Barat.

Metode

Penelitian potong lintang ini melibatkan 120 pekerja Penanganan Prasarana dan Sarana Umum (PPSU) dari tiga kelurahan: Cengkareng, Rawa Buaya, dan Cengkareng Timur. Kualitas udara diukur menggunakan data dari stasiun pemantauan terdekat, dengan menilai kadar PM2.5 dan Indeks Kualitas Udara (IKU). Penilaian kesehatan mencakup anamnesis, kuesioner yang diisi mandiri oleh pasien, uji waktu transit sakarin, dan pemeriksaan endoskopi otorhinolaringologi.

Hasil

Rerata kadar PM2.5 adalah 57,58 µg/m³ (berisiko tinggi terhadap gangguan pernapasan), dan nilai IKU adalah 144,71 µg/m³ (tidak sehat). Rerata waktu transit sakarin adalah 427,29 detik, dengan panjang dasar rongga hidung rata-rata 63,76 mm. Prevalensi rinofaringitis akut adalah 59,2%, rinosinusitis akut 8,3%, rinitis okupasi 9,2% dan insufisiensi vitamin D 67,5%. Namun, tidak ditemukan hubungan yang signifikan antara paparan polusi udara, fungsi mukosiliar, dan penyakit otolaringologis akut ($p > 0,05$).

Kesimpulan

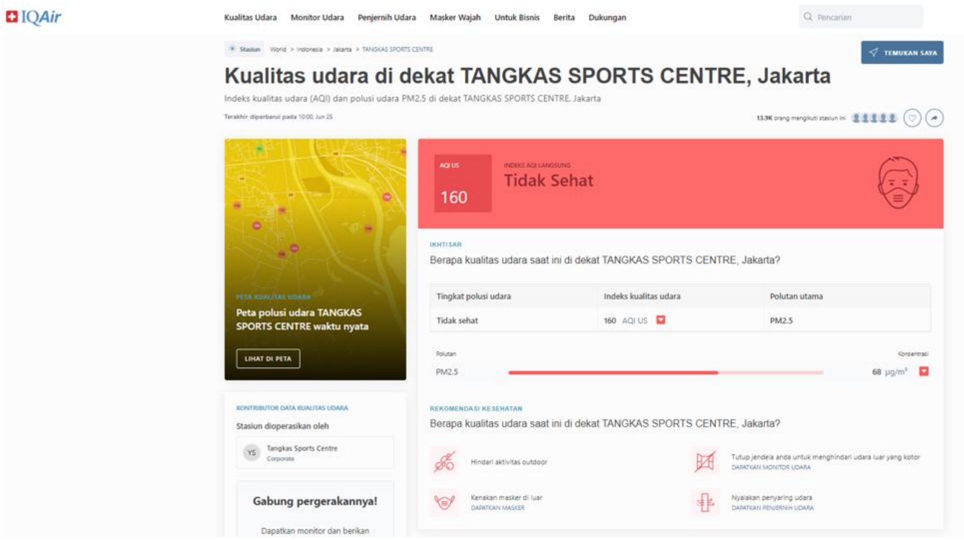
Meskipun terdapat paparan polusi udara yang tinggi, tidak ditemukan hubungan yang signifikan antara polusi udara, pembersihan mukosiliar, dan penyakit otolaringologis akut pada pekerja luar ruangan. Penelitian lanjutan dengan ukuran sampel yang lebih besar dan desain longitudinal diperlukan.

Kata Kunci: Bersihan mukosilia; Pekerja luar ruangan; PM2.5; Penyakit akut otolaringologi; Polusi udara; uji waktu transit sakarin.

INTRODUCTION

Air pollution has become a major public health concern in many urban areas, including Jakarta. West Jakarta, as one of the most densely populated and industrially active regions, frequently records elevated concentrations of fine particulate matter 2.5 (PM2.5).[1] Real-time data from the six monitoring stations during August 2024 in West Jakarta showed an unhealthy category in the Air Quality Index (AQI) and PM2.5 concentration.[2] Prolonged exposure to PM2.5 can impair respiratory function and increase susceptibility to various diseases of the upper respiratory tract, including those affecting the ear, nose, and throat (ENT).[1,3–5]

Public Facilities and Infrastructures (*Penanganan Prasarana dan Sarana Umum* or PPSU) officers constitute a workforce with continuous outdoor exposure, making them particularly vulnerable to ambient air pollution.[6–7] Although numerous studies have examined the impact of poor air quality on chronic respiratory diseases such as asthma and allergic rhinitis[8-9], evidence on the effects of short-term particulate exposure on *acute* ENT infections, especially among outdoor workers, remains limited.[10–11] This gap is important because acute ENT conditions, including rhinitis, rhinosinusitis, rhinopharyngitis, and pharyngitis, can reduce productivity, increase absenteeism, and impair quality of life.[12–13]



Picture 1. Air quality on Tuesday, June 25, 2024, was taken from the Tangkas Sports Centre station in West Jakarta.[2]

A key physiological defense mechanism against inhaled pollutants is mucociliary clearance (MCC), which transports inhaled particles away from the upper airway through coordinated mucociliary activity and mucus flow.[14–15] Experimental studies indicate that PM2.5 can disrupt MCC by inducing epithelial inflammation, oxidative stress, and mucociliary dysfunction.[15–21] However, field-based evidence linking MCC impairment to acute ENT symptoms among outdoor workers remains scarce, particularly in Southeast Asia, where urban pollution levels are high, and exposure patterns differ from those in temperate countries.

In addition to air pollution and MCC, serum vitamin D status has been proposed as another factor influencing mucosal immunity and upper airway inflammation. Several studies have reported associations between low vitamin D status and the severity of rhinosinusitis [22,23], but its role in acute ENT illnesses among outdoor workers in Indonesia is poorly understood. Given that PPSU workers spend most of their time under direct sunlight, assessing vitamin D status provides additional insight into host vulnerability and environmental interactions, not as a primary endpoint, but as a relevant biological modifier.

Therefore, this study aims to fill two key gaps: (1) limited community-based evidence linking short-term ambient air pollution exposure, MCC function, and acute ENT infections among outdoor workers, and (2) limited understanding of how individual factors, including vitamin D status, may modify susceptibility to these infections. The findings of this study are expected to strengthen preventive strategies of occupational ENT health risks to improve respiratory health and work performance among PPSU workers.

METHODS

Study Design and Population

This cross-sectional study included 120 Public Facilities and Infrastructure Officers (PPSU) working in West Jakarta, specifically in Cengkareng, Rawa Buaya, and East Cengkareng. Data collection took place between 2 and 9 September 2025. Ethical approval was obtained from the Ethics Committee of the Faculty of Medicine, Universitas Trisakti (No. 091/KER/FK/08/2024).

Inclusion and Exclusion Criteria

Eligible participants were adults aged 20–50 years, subjectively healthy (no fever, cough, or common cold symptoms), with at least 1 year of continuous employment. Exclusion criteria included: congenital ear or hearing abnormalities (e.g., anotia, microtia/macrotia, congenital sensorineural hearing loss), congenital nasolabial abnormalities (cleft lip/palate), nasal bone deformities due to trauma, thyroid disorders, ENT malignancies, prior ENT or head-and-neck reconstructive surgery, and history or known allergy diagnosis. Respondents with incomplete data were excluded.

Air Pollution Exposure Assessment

Ambient outdoor air pollution exposure parameters, including daily AQI and PM2.5 concentrations throughout August 2024, were recorded at six points near the nearest fixed-site monitor to the study locations, namely Tangkas Sports Centre Station (Duri Kepa, West Jakarta), Nfinitefx Station (South Kembangan, West Jakarta), Tatalogam Tower Station (Duri Kepa, West Jakarta), Duitku PG Station (Kebon Jeruk, West Jakarta), Taman Resort Mediterania (Kapuk Muara, West Jakarta), and Puretex Indonesia Station (Kalideres, West Jakarta). Data were obtained from IQAir (iqair.com), tabulated, and the average concentration was calculated (Table 1). [(2)] Fixed-site monitoring was used as a validated proxy for area-level short-term exposure when personal monitoring is infeasible.[1,22]

Clinical Assessment

Subjective complaints were recorded using standardized, self-administered, Indonesian-validated patient-reported outcome questionnaires (PROQs), including the Nasal Obstruction Symptoms Evaluation (NOSE). Anamnesis included criteria from the European Position Paper on Rhinosinusitis and Nasal Polyps (EPOS) 2020: nasal obstruction, nasal discharge (anterior or posterior), facial tenderness, and disturbances in smell (hyposmia, anosmia, or parosmia). Rhinosinusitis refers to a population having subjective complaints as defined by criteria from EPOS 2020, any mucosal edema and/or mucopurulent discharge primarily in the middle meatus seen endoscopically and reported a mild to significant nasal NOSE score. Acute refers to complaints lasting for below 12 weeks.

Annual Illness frequencies (fallen sick or recorded sick leaves), the use of personal protective equipment (PPE) during working hours, and subjective complaints of worsening associated with working were also noted. Thus, the sample with complaints about rhinosinusitis corresponded with work referred to as occupational rhinitis. Acute rhinopharyngitis was defined as a sample with a complaint of nasal and throat inflammation and was confirmed by endoscopic findings.

Digitally recorded endoscopic otoscopy, rhinoscopy, and throat examinations were performed by otolaryngologists. The nasal floor was measured using the shaft of the endoscopic telescope. The telescope shaft was positioned adjacent to the ground, placed along the inferior meatus of either wider nasal cavity. The end lens was advanced until the posterior end of the perpendicular plate. A tape was then placed in the shaft just before the vestibulum. The length was recorded and reduced by 1 cm, given the estimated average length of the nasal vestibulum. The resulting measurement was considered the total length of the nasal floor in cm.

Mucociliary Clearance (MCC) Assessment

The MCC was measured using the saccharin transit time test: a 1-mm saccharin particle was placed on the nasal floor, 1 cm from the head of the inferior turbinate. Participants swallowed every 30–60 seconds, and the time to the first sweet taste was recorded in seconds.[14–17,19]

Vitamin D Assessment

Serum 25-hydroxyvitamin D levels were measured in venous samples analyzed at a certified clinical laboratory. Vitamin D status was categorized as normal (30 – 100 ng/mL), insufficient (21 – 29 ng/mL), or deficient (<20 ng/mL).

Confounding Variables

Other outdoor pollutants, such as PM10, ozone, nitrogen oxide (NO), carbon monoxide (CO), sulfur dioxide (SO2), and other outdoor volatile organic compounds (VOCs), were not included in this research. Indoor and other personal pollutant exposure, including active or passive smoking habits; use of household or daily cleaners, including laundry detergents, paints, air fresheners, chemical polishers, and gas appliances; exposure to mold, dust mites, pet dander, pollen, and cockroaches; and exposure to other building materials such as asbestos, was not assessed in this study. Allergic history or known diagnosis, chronic respiratory disease, and **nutritional status** were excluded from this population. Sun exposure, body surface area exposed to the sun, and total daily sunlight were not accounted for. These represent important uncontrolled confounders and are acknowledged as methodological limitations.

Data Analysis

Analyses were conducted in SPSS v29 and R v4.3. Descriptive statistics: frequencies, percentages, and means ± SD. Bivariate analyses: chi-square tests for categorical variables; independent t-tests or Mann–Whitney U tests for continuous variables. Multivariate logistic regression examined predictors of subjective rhinopharyngitis complaints; independent variables included age, sex, mask use, MCC time (s), nasal length, nasal transport speed (mm/s), vitamin D status, and PM2.5 (per 10 μg/m³). Model fit was assessed by the Hosmer–Lemeshow test; discrimination by AUC; multicollinearity by VIF.

RESULTS

Air Quality and Exposure

Table 1 presents PM2.5 data from six West Jakarta stations (August 2024): mean PM2.5 across stations = 57.58 μg/m³, mean AQI (US) = 144.71. These values exceed WHO guideline values (annual 5 μg/m³; 24-h 15 μg/m³)[23] and are comparable to levels associated with adverse respiratory outcomes.[1,3–5] The Indonesian 24-hour standard (65 μg/m³) was also considered.[24]

Respondents' Characteristics

A total of 120 PPSU workers participated. The mean age was 40.39 ± 8.42 years. Most participants were male (90.0%), and 67.5% reported inconsistent mask use during working hours. Vitamin D insufficiency was present in 67.5%, and deficiency in 0.83% of the population. Saccharin transit time (STT) ranged from 9 to 1867 seconds (mean 427.29 ± 327.37 s). Mean nasal floor length was 64.22 ± 6.78 mm; mean mucociliary clearance velocity was 0.38 ± 0.87 mm/s. The average PM2.5 level during August 2024 ranged from 35.7 to 62.8 μg/m³, and the average AQI was 101–156. The prevalence of rhinopharyngitis was 59.2%, rhinosinusitis 8.3%, and occupational rhinitis 9.2%. Among subjects with rhinosinusitis, the prevalence of vitamin D insufficiency was 80%.

Table 1. PM 2.5 Data (August 2024).[2]

Date	Stasiun Tangkas Sports Centre, Duri Kepa, West Jakarta		Stasiun nfinitefx, Puri Indah, South Kembangan, West Jakarta		Tatalogam Tower, Duri Kepa, West Jakarta		Duitku PG, Kebon Jeruk, West Jakarta		Taman Resort Mediterania, Kapuk Muara, West Jakarta		Puretex Indonesia, Tegal Alur / Kalideres, West Jakarta		AVERAGE	
	PM2.5	AQI US	PM2.5	AQI US	PM2.5	AQI US	PM2.5	AQI US	PM2.5	AQI US	PM2.5	AQI US	PM2.5	AQI US
1	77	166	83.6	171	83.5	171	73.3	163	61.5	155	66.6	159	74.25	164.17
2	40.5	113	47.2	130	43.5	121	40	112	35.2	100	40.3	113	41.12	114.83
3	47.3	130	55.5	151	55.5	151	49.8	136	45.1	125	43.7	121	49.48	135.67
4	51.8	141	59.1	154	55.7	151	51.9	141	42.2	117	41.4	116	50.35	136.67
5	44.1	122	48.2	132	48	132	42.9	119	34.8	99	40.8	114	43.13	119.67
6	47.2	130	56.7	152	56.6	152	50.4	138	38.9	109	39.5	111	48.22	132.00
7	60	154	75.7	165	67.2	159	65.2	158	52	142	53.6	146	62.28	154.00
8	61.5	155	72.5	163	67.3	159	61	155	53.1	144	51.3	140	61.12	152.67
9	40.5	113	50.6	138	46.2	127	46	127	43.2	120	43.4	120	44.98	124.17
10	51.9	141	58.8	153	54	147	51.6	141	39.7	111	40.8	114	49.47	134.50
11	50.7	138	61.8	155	55.5	151	50.7	138	37.9	107	41.4	116	49.67	134.17
12	47	129	60.4	154	58.3	153	53.7	146	44.2	122	44.5	123	51.35	137.83
13	50	137	64.3	157	61.8	155	61.3	155	53	144	49.4	135	56.63	147.17
14	58.2	153	66.4	159	60.2	154	57.5	152	56.3	152	60.4	154	59.83	154.00
15	60	154	68.7	160	65.5	158	59.8	154	53	144	53.6	146	60.10	152.67
16	63.5	157	80	168	71.8	162	66.8	159	57.7	153	55.4	150	65.87	158.17
17	55.5	151	72.5	163	65.7	158	61.1	155	49.3	135	48.7	134	58.80	149.33
18	51	139	63.8	157	57.2	152	55.3	150	45.2	125	43.3	120	52.63	140.50
19	61.8	155	84.8	172	70.3	161	69.9	161	60.3	154	62.8	156	68.32	159.83
20	70.2	161	97	180	81.5	169	81.3	169	59.2	154	79.8	168	78.17	166.83
21	62.4	156	70.7	162	67.6	159	62	156	53.4	145	56	151	62.02	154.83
22	38.2	108	42	117	42.9	119	38.9	109	35.5	101	35.7	101	38.87	109.17
23	61.8	155	72.7	163	66.1	158	61.5	155	49.8	136	61.5	155	62.23	153.67
24	78.5	167	88.3	174	81.7	169	77.5	166	62.3	156	64.4	157	75.45	164.83
25	43	119	61.7	155	53.5	145	53.9	146	42.6	118	41.6	116	49.38	133.17
26	74.5	164	85.6	172	77.9	167	72.6	163	67	159	69.5	161	74.52	164.33
27	56	151	59.5	154	58.5	153	51.3	140	53.6	146	54	147	55.48	148.50
28	60.9	155	78.7	167	64.4	157	63.3	156	49.6	136	72.8	163	64.95	155.67
29	74.4	164	89.1	175	85.5	172	77.8	167	67.2	159	79.3	168	78.88	167.50
30	45.9	127	60	154	53	144	50.2	137	47.1	130	51.5	140	51.28	138.67
31	40.9	114	58.9	153	46.3	128	48.3	133	40.3	113	43.1	120	46.30	126.83
Rerata	55.68	142.55	67.57	157.42	62.02	152.06	58.28	147.00	49.36	132.61	52.58	136.61	57.58	144.71

Notes: PM2.5 levels (μg/m^3)

Bivariate Analysis

Tables 2 and 3 show associations between characteristics and rhinopharyngitis and occupational rhinitis. None of the examined categorical variables (sex, age group, mask use, vitamin D status) showed significant bivariate associations with rhinopharyngitis (all $p > 0.05$). Similarly, no significant associations were observed for occupational rhinitis.

Table 2. Association Between Respondents' Characteristics and Rhinopharyngitis

Variable	Rhinopharyngitis		p-value
	No (n (%))	Yes (n (%))	
Sex			
Male	83(76.9%)	25(23.1%)	0.481#
Female	8(66.7%)	4(33.3%)	
Age			
20-40 years	42(72.4%)	16(27.6%)	0.309C
41-60 years	49(80.3%)	12(19.7%)	
Mask Use at Work			
Tidak	59(72.8%)	22(27.2%)	0.270C
Ya	32(82.1%)	7(17.9%)	
Serum Vitamin D3 25-OH levels			
Normal	30(76.9%)	9(23.1%)	0.368C
Insufifciency	46(71.9%)	18(28.1%)	
Deficiency	15(88.2%)	2(11.8%)	
Legend: n = frequency; % = percentage; C = Chi-square test; # = Fisher's Exact test			

Table 3. Association Between Respondents' Characteristics and Work-Related Rhinitis (Occupational Rhinitis)

Variable	Work-Related Rhinitis		p-value
	No (n (%))	Yes (n (%)	
Sex			
Male	98(90.7%)	10(9.3%)	1.000#
Female	11(91.7%)	1(8.3%)	
Age			
20-40 years	51(86.4%)	8(13.6%)	0.101C
41-60 years	48(95.1%)	3(4.9%)	
Mask Use at Work			
Tidak	76(93.8%)	5(6.2%)	0.173#
Ya	33(84.6%)	6(15.4%)	
Serum Vitamin D3 25-OH levels			
Normal	37(94.9%)	2(5.1%)	0.500#
Insufifciency - Deficiency	72(88.9%)	9(11.1%)	
Legend: n= frequency; %=percentage C= Chi-square test; #=*Fisher's Exact test*			

Multivariate Logistic Regression Analysis

A multivariate logistic regression model was developed to examine the simultaneous effects of demographic characteristics, mucociliary clearance function, vitamin D status, nasal anatomical variables, and short-term PM2.5 exposure on the likelihood of subjective rhinopharyngitis. Variables with theoretical relevance and those with $p < 0.25$ in bivariate analysis were included in the adjusted model.

Model Results

Table 4 presents the adjusted odds ratios (AOR), 95% confidence intervals (CI), and corresponding p-values. None of the predictors reached statistical significance, indicating that no single factor independently explained the occurrence of subjective rhinopharyngitis after adjusting for confounders. However, several trends were observed.

Tabel 4. Adjusted Odds Ratios for Predictors of Subjective Rhinopharyngitis

Variable	OR	95% CI	p -value
Age (per year)	.98	0.92– 1.03	0 .369
Female sex	.87	0.74– 20.07	0 .108
MCC time (per second)	.001	1.000 –1.002	0 .187
Mask use	.56	0.20– 1.51	0 .249
Vit D insufficiency vs normal	.01	0.37– 2.72	0 .992
Vit D deficiency vs normal	.18	0.02– 1.38	0 .099
Nasal length (per mm)	.97	0.90– 1.03	0 .299
Mucociliary clearance velocity (mm/s)	.06	0.65– 1.73	0 .821
PM2.5 per 10 μg/m³	**.69**	**0.15– 49.56**	**0 .507**

Although none of the variables were statistically significant, several clinically meaningful patterns emerged. Female sex was associated with higher adjusted odds of reporting rhinopharyngitis (AOR 3.87), suggesting possible sex-based susceptibility, though the confidence intervals were wide due to the small female sample size. Longer MCC time showed a trend toward increased risk (AOR 1.001), supporting the physiological plausibility that impaired mucociliary clearance may predispose to upper airway infection. Vitamin D deficiency appeared protective in the adjusted model (AOR 0.18), though this counterintuitive result likely reflects the sample distribution rather than a true biological effect. Higher short-term PM2.5 exposure was associated with increased odds of symptoms (AOR 2.69), but the CIs were extremely wide due to limited daily variation across the study period.

Overall, the multivariate model indicates that subjective rhinopharyngitis among PPSU workers likely results from a multifactorial interplay rather than a single dominant predictor. Larger studies with broader exposure ranges and additional confounding variables (e.g., smoking history, allergy status, chronic illness, dietary factors) may better clarify these relationships.

DISCUSSION

This study's analysis detected no statistically significant associations between short-term PM2.5 exposure, MCC, vitamin D status, or demographic characteristics and rhinosinusitis, rhinopharyngitis, or occupational rhinitis. Despite PM2.5 levels during the sampling period exceeding WHO-recommended limits, reaching 35.7–62.8 μg/m³, they were comparable to pollution levels associated with adverse respiratory outcomes in previous research.[1,23] These findings highlight the complexity of upper respiratory disease pathogenesis and suggest that ENT morbidity cannot be explained by a single environmental or physiological factor alone.

Previous studies have shown that air pollution, particularly PM2.5, contributes to upper respiratory tract inflammation, allergic rhinitis, asthma, and otitis media.[3,7-10] Proposed biological mechanisms include epithelial damage, impaired mucociliary function, altered mucin composition, and dysregulated mucosal immunity.[14-18] Urban PM2.5 has been shown to induce mucociliary remodeling at the genomic level, reducing epithelial resilience and altering innate immune responses.[15] Moreover, the chemical composition of particulates can exacerbate toxic effects on the mucociliary epithelium.[16] Although these mechanisms suggest a plausible link between pollution and ENT symptoms, the present study's null findings likely reflect methodological and analytical limitations rather than the absence of a biological relationship.

Mucociliary clearance times in this study showed considerable variability, ranging from 9 to 1867 seconds. Although some respondents demonstrated prolonged clearance, the mean MCC remained broadly within the ranges reported in healthy individuals.[14] The saccharin transit test, while widely used, lacks sensitivity to detect mild or chronic mucociliary dysfunction and may underestimate mucociliary impairment induced by prolonged particulate exposure.[19, 21] Technical faults may also contribute to the wide range, particularly when the sample inhales the saccharin particle rather than it traveling through the nasal mucus blanket. Technique execution should be a concern. Subject's position, the manner of saccharin particle introduction, saccharin particle size, and guidance to the sample subject may influence the result. Mucociliary transport may be influenced by age, nasal septal deviation, smoking habit, physical activity in daily life, alcohol or caffeine consumption, use of drugs that may affect MCC, circadian cycle, and environmental conditions. Anticholinergics, aspirin, anesthetics, and benzodiazepines may decrease MCC. Chronic rhinosinusitis medications such as cholinergics, methylxanthines, anti-asthmatics, antibiotics (penicillin, cephalosporin, and sulphonamide), surfactant, hypertonic saline solution, and water aerosol may improve MCC.[21]

Rodrigues et al.[21] suggested performing the test in a seated position in a quiet room, with a room temperature of 25°C, humidity of 50–60%, and air conditioning and a humidifier recommended to control the examination room environment. Subjects were asked to abstain from alcohol, caffeine, cigarettes, and drugs for at least 12 hours prior to evaluation. No strenuous physical activity was allowed 24 hours before the examination. A plastic straw was trimmed to facilitate deposition of saccharin particles within the nose. The amount of saccharin particles was standardized at 2.5 µg, rather than by the diameter or size of the saccharin. The subject's head position was slightly extended, approximately 10° of neck extension. The saccharin particle was placed 2 cm into the inferior turbinate. Subjects were asked not to get up, talk, cough, sneeze, or in any way manipulate their nose. If this occurred, the test was rescheduled for another day. The expected flavor and nature of the substance were not disclosed to the subject to prevent false positives. [21]

The mean saccharin transit time (STT) in this study was 427.29 ± 327.37 s (≈ 7.12 ± 5.46 minutes). The normal average mucociliary transit time is 12 – 15 minutes; more than 20 minutes is considered prolonged and indicates a disturbance in the MCC.[14] Resmi et al. found the average STT in wood factory workers was 18.22 ± 3.874 minutes.[20] Priscilla et al. found a higher STT in adult women exposed to biomass fuel than in adult women who used clean fuel.[21] Ferreira Ceccato et al. did not find a difference in STT between smokers and nonsmokers among sugarcane cutters.[21] The significantly lower mean STT in this study was due to a technical fault. The technique of depositing saccharin particles, along with subject instruction to not talk during the examination, may interfere with the result, as the particles may be inhaled and carried by the nasal airflow.

Vitamin D insufficiency was present in two-thirds of respondents; deficiency was found to be less than 1%. Sowah et al. conducted a systematic review and found that combined rates of vitamin D deficiency or insufficiency were very high among indoor, outdoor, and shift workers, as well as healthcare workers, including medical residents, healthcare students, practicing physicians, nurses, and other healthcare personnel.[22] Sowah et al.[22] found that 75.2% of subjects had vitamin D insufficiency. While Goswami et al.[23] found that 40.63% of outdoor workers with type 2 diabetes mellitus in Southern West Bengal had insufficient vitamin D and 2.34% had deficient vitamin D.[23] Goswami et al. attributed their findings to sufficient duration of sun exposure during working hours and total daily sunlight.[23] While our study was conducted during August – September, which is the summer season in Jakarta, we did not account for duration of sun exposure or total daily sunlight the subjects may receive. Sowah et al.22 added that other determinants of vitamin D deficiency include culture, geography, genetics, disease states, diet, and age. No relationship was found with acute ENT symptoms in this study. This discrepancy may reflect differences in disease pathophysiology, insufficient sample size, or confounding factors such as sunlight exposure patterns, diet, and use of protective equipment among outdoor workers.

The prevalence of rhinopharyngitis in this study was 59.2%. However, the absence of statistically significant associations in the multivariate analysis highlights the multifactorial nature of ENT diseases. Teeranoraseth et al. found rhinopharyngitis to be the leading upper respiratory tract infection (URTI) causing Thai people to visit a tertiary hospital during 2017–2019. They also reported a significant correlation between PM2.5 and acute URTIs.[24] This inconsistency may be due to sample size and demographics. This study's sample consisted of outdoor workers without symptoms of URTI. The sample size was also smaller than that of Teeranoraseth. Host factors (genetic predisposition, smoking, allergic history), occupational variables (duration of exposure, type of outdoor tasks), and environmental factors (humidity, co-exposure to allergens or pathogens) may all contribute but were not assessed in this study.

Using fixed-site monitoring stations rather than personal air pollution sensors may have contributed to exposure misclassification, particularly given microenvironmental differences within urban areas. The cross-sectional design further limits causal inference because temporal relationships cannot be established. These limitations reflect common challenges in environmental epidemiology but underscore the need for more robust study designs to disentangle complex exposure–response relationships.

Strengths and Limitations

This study offers several methodological strengths, including ENT examinations performed by specialists, objective assessments of mucociliary clearance, and laboratory-confirmed vitamin D measurements. Environmental exposure was contextualized using PM2.5 data from the six nearest monitoring stations, providing reliable area-level pollution estimates consistent with WHO reporting standards.[1,25]

However, important limitations should be noted. First, the cross-sectional design precludes causal inference and limits interpretation of temporal associations. Second, pollution exposure was estimated using fixed-site monitoring stations rather than personal sensors, which may lead to exposure misclassification. Third, many key confounding variables, including other outdoor and indoor pollutants, smoking status, allergic disease history, chronic respiratory conditions, nutritional status, sun exposure, and nonoccupational pollution exposure, were not measured.[6,7,26] Fourth, the saccharin transit time test posed technical difficulties and may have insufficient sensitivity to detect mild mucociliary dysfunction, potentially attenuating measurable associations.[14,19] Finally, limited variability in PM2.5 levels during the study period and a moderate sample size reduce the statistical power to detect small effect sizes.

Implications for Practice

Despite the lack of statistically significant associations, the high prevalence of acute ENT symptoms and widespread vitamin D insufficiency among PPSU workers underscore the importance of occupational health interventions for urban outdoor workers. Routine ENT screening, training on the proper and consistent use of respiratory protective equipment, particularly N95 or equivalent masks, and workplace health education may help reduce the disease burden. Regular vitamin D screening and supplementation may be beneficial when insufficiency and/or deficiency are detected. At the public health level, strengthening environmental policies to reduce particulate emissions remains crucial, in line with WHO air quality recommendations [1,25]. Future studies with larger sample sizes, incorporating longitudinal designs, personal exposure monitoring, and comprehensive assessment of lifestyle and health-related confounders are needed to build stronger evidence and inform targeted prevention strategies.

CONCLUSION

In conclusion, although this study found no statistically significant associations between PM2.5 exposure, mucociliary clearance, vitamin D status, demographic factors, and acute ENT symptoms, the high prevalence of acute rhinopharyngitis, acute rhinosinusitis, occupational rhinitis, and vitamin D insufficiency among PPSU outdoor workers remains a concern. These null findings likely reflect methodological constraints and the complex, multifactorial nature of upper respiratory disease rather than the absence of environmental effects. Longitudinal studies with improved exposure assessment and comprehensive confounder control are needed to clarify the environmental determinants of ENT morbidity in outdoor occupational settings.

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AUTHORS CONTRIBUTION

The authors confirm their contributions to the paper as follows: study conception and design: PT, TM; data collection: TM, DA, FA; analysis and interpretation of results: PT, TM; manuscript drafting: PT, TM. All authors reviewed the results and approved the final version of the manuscript.

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CONFLICT OF INTEREST

Competing interests: No relevant disclosures.

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Air Pollution and the Risk of Acute Ear, Nose, and Throat Diseases- A Cross-Sectional Study in West Jakarta

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ORIGINAL ARTICLE

Air Pollution and the Risk of Acute Ear, Nose, and Throat Diseases: A Cross-Sectional Study in West Jakarta

Polusi Udara dan Risiko Penyakit Akut pada Telinga, Hidung, dan Tenggorok: Studi Cross-Sectional di Jakarta Barat

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ABSTRACT

Background

Air pollution, particularly in urban areas such as West Jakarta, is a major public health concern. Long-term exposure to pollutants, including particulate matter (PM) 2.5, can lead to respiratory problems, including acute otolaryngologic diseases. Outdoor workers, such as those involved in urban infrastructure maintenance, are more vulnerable to these conditions. This study aimed to assess the relationship among air pollution levels, mucociliary clearance function, and the prevalence of acute otolaryngologic diseases among outdoor workers in West Jakarta.

Methods

A cross-sectional study was conducted among 120 Public Infrastructure and Facility Maintenance (PPSU) workers in the Cengkareng, Rawa Buaya, and Cengkareng Timur sub-districts. Air quality was assessed using data from nearby monitoring stations, measuring PM2.5 levels and the Air Quality Index (AQI). Health assessments included anamnesis, patient-reported outcome questionnaires, saccharin transit test, and otorhinolaryngologic endoscopic assessments.

Results

The average PM2.5 level was 57.58 µg/m³ (high risk for respiratory issues), and the AQI was 144.71 µg/m³ (unhealthy). The saccharin transit time test averaged 427.29 seconds, with a mean nasal floor length of 63.76 mm. The prevalence of acute rhinopharyngitis was 59.2%, rhinosinusitis 8.3%, occupational rhinitis 9.2%, and vitamin D insufficiency 67.5%. However, no significant correlation was found between air pollution exposure, mucociliary function, and acute otolaryngologic diseases ($p > 0.05$).

Conclusions

Despite high exposure to air pollution, no significant relationship was observed between air pollution, mucociliary clearance, and acute otolaryngologic diseases among PPSU workers. Further studies with larger sample sizes and longitudinal designs are needed.

Keywords: Air pollution; Acute otolaryngologic diseases; Mucociliary clearance; Saccharin transit time test; Outdoor workers; PM2.5.

ABSTRAK

Latar Belakang

Polusi udara, terutama di daerah perkotaan seperti Jakarta Barat, merupakan masalah kesehatan masyarakat yang serius. Paparan jangka panjang terhadap polutan seperti materi partikulat (PM) 2.5 dapat menyebabkan gangguan pernapasan, termasuk penyakit otolaringologis akut. Pekerja luar ruangan, seperti mereka yang terlibat dalam pemeliharaan infrastruktur kota, lebih rentan terhadap kondisi tersebut. Penelitian ini bertujuan untuk menilai hubungan antara tingkat polusi udara, fungsi pembersihan mukosilia, dan prevalensi penyakit otolaringologis akut pada pekerja luar ruangan di Jakarta Barat.

Metode

Penelitian potong lintang ini melibatkan 120 pekerja Penanganan Prasarana dan Sarana Umum (PPSU) dari tiga kelurahan: Cengkareng, Rawa Buaya, dan Cengkareng Timur. Kualitas udara diukur menggunakan data dari stasiun pemantauan terdekat, dengan menilai kadar PM2.5 dan Indeks Kualitas Udara (IKU). Penilaian kesehatan mencakup anamnesis, kuesioner yang diisi mandiri oleh pasien, uji waktu transit sakarin, dan pemeriksaan endoskopi otorhinolaringologi.

Hasil

Rerata kadar PM2.5 adalah 57,58 µg/m³ (berisiko tinggi terhadap gangguan pernapasan), dan nilai IKU adalah 144,71 µg/m³ (tidak sehat). Rerata waktu transit sakarin adalah 427,29 detik, dengan panjang dasar rongga hidung rata-rata 63,76 mm. Prevalensi rinofaringitis akut adalah 59,2%, rinosinusitis akut 8,3%, rinitis okupasi 9,2% dan insufisiensi vitamin D 67,5%. Namun, tidak ditemukan hubungan yang signifikan antara paparan polusi udara, fungsi mukosiliar, dan penyakit otolaringologis akut ($p > 0,05$).

Kesimpulan

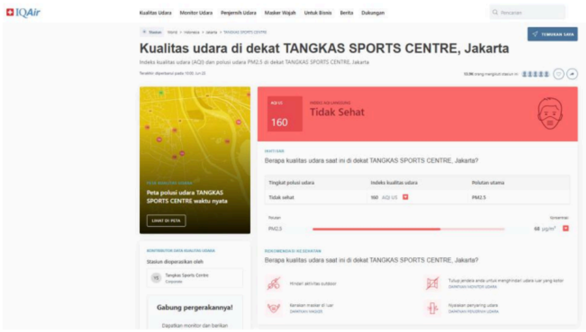
Meskipun terdapat paparan polusi udara yang tinggi, tidak ditemukan hubungan yang signifikan antara polusi udara, pembersihan mukosiliar, dan penyakit otolaringologis akut pada pekerja luar ruangan. Penelitian lanjutan dengan ukuran sampel yang lebih besar dan desain longitudinal diperlukan.

Kata Kunci: Bersihan mukosilia; Pekerja luar ruangan; PM2.5; Penyakit akut otolaringologi; Polusi udara; uji waktu transit sakarin.

INTRODUCTION

Air pollution has become a major public health concern in many urban areas, including Jakarta. West Jakarta, as one of the most densely populated and industrially active regions, frequently records elevated concentrations of fine particulate matter 2.5 (PM2.5).[1] Real-time data from the six monitoring stations during August 2024 in West Jakarta showed an unhealthy category in the Air Quality Index (AQI) and PM2.5 concentration.[2] Prolonged exposure to PM2.5 can impair respiratory function and increase susceptibility to various diseases of the upper respiratory tract, including those affecting the ear, nose, and throat (ENT).[1,3–5]

Public Facilities and Infrastructures (*Penanganan Prasarana dan Sarana Umum* or PPSU) officers constitute a workforce with continuous outdoor exposure, making them particularly vulnerable to ambient air pollution.[6–7] Although numerous studies have examined the impact of poor air quality on chronic respiratory diseases such as asthma and allergic rhinitis[8-9], evidence on the effects of short-term particulate exposure on *acute* ENT infections, especially among outdoor workers, remains limited.[10–11] This gap is important because acute ENT conditions, including rhinitis, rhinosinusitis, rhinopharyngitis, and pharyngitis, can reduce productivity, increase absenteeism, and impair quality of life.[12–13]



Picture 1. Air quality on Tuesday, June 25, 2024, was taken from the Tangkas Sports Centre station in West Jakarta.[2]

A key physiological defense mechanism against inhaled pollutants is mucociliary clearance (MCC), which transports inhaled particles away from the upper airway through coordinated mucociliary activity and mucus flow.[14–15] Experimental studies indicate that PM2.5 can disrupt MCC by inducing epithelial inflammation, oxidative stress, and mucociliary dysfunction.[15–21] However, field-based evidence linking MCC impairment to acute ENT symptoms among outdoor workers remains scarce, particularly in Southeast Asia, where urban pollution levels are high, and exposure patterns differ from those in temperate countries.

In addition to air pollution and MCC, serum vitamin D status has been proposed as another factor influencing mucosal immunity and upper airway inflammation. Several studies have reported associations between low vitamin D status and the severity of rhinosinusitis [22,23], but its role in acute ENT illnesses among outdoor workers in Indonesia is poorly understood. Given that PPSU workers spend most of their time under direct sunlight, assessing vitamin D status provides additional insight into host vulnerability and environmental interactions, not as a primary endpoint, but as a relevant biological modifier.

Therefore, this study aims to fill two key gaps: (1) limited community-based evidence linking short-term ambient air pollution exposure, MCC function, and acute ENT infections among outdoor workers, and (2) limited understanding of how individual factors, including vitamin D status, may modify susceptibility to these infections. The findings of this study are expected to strengthen preventive strategies of occupational ENT health risks to improve respiratory health and work performance among PPSU workers.

METHODS

Study Design and Population

This cross-sectional study included 120 Public Facilities and Infrastructure Officers (PPSU) working in West Jakarta, specifically in Cengkareng, Rawa Buaya, and East Cengkareng. Data collection took place between 2 and 9 September 2025. Ethical approval was obtained from the Ethics Committee of the Faculty of Medicine, Universitas Trisakti (No. 091/KER/FK/08/2024).

Inclusion and Exclusion Criteria

Eligible participants were adults aged 20–50 years, subjectively healthy (no fever, cough, or common cold symptoms), with at least 1 year of continuous employment. Exclusion criteria included: congenital ear or hearing abnormalities (e.g., anotia, microtia/macrotia, congenital sensorineural hearing loss), congenital nasolabial abnormalities (cleft lip/palate), nasal bone deformities due to trauma, thyroid disorders, ENT malignancies, prior ENT or head-and-neck reconstructive surgery, and history or known allergy diagnosis. Respondents with incomplete data were excluded.

Air Pollution Exposure Assessment

Ambient outdoor air pollution exposure parameters, including daily AQI and PM2.5 concentrations throughout August 2024, were recorded at six points near the nearest fixed-site monitor to the study locations, namely Tangkas Sports Centre Station (Duri Kepa, West Jakarta), Nfinitefx Station (South Kembangan, West Jakarta), Tatalogam Tower Station (Duri Kepa, West Jakarta), Duitku PG Station (Kebon Jeruk, West Jakarta), Taman Resort Mediterania (Kapuk Muara, West Jakarta), and Puretex Indonesia Station (Kalideres, West Jakarta). Data were obtained from IQAir (iqair.com), tabulated, and the average concentration was calculated (Table 1). [(2)] Fixed-site monitoring was used as a validated proxy for area-level short-term exposure when personal monitoring is infeasible.[1,22]

Clinical Assessment

Subjective complaints were recorded using standardized, self-administered, Indonesian-validated patient-reported outcome questionnaires (PROQs), including the Nasal Obstruction Symptoms Evaluation (NOSE). Anamnesis included criteria from the European Position Paper on Rhinosinusitis and Nasal Polyps (EPOS) 2020: nasal obstruction, nasal discharge (anterior or posterior), facial tenderness, and disturbances in smell (hyposmia, anosmia, or parosmia). Rhinosinusitis refers to a population having subjective complaints as defined by criteria from EPOS 2020, any mucosal edema and/or mucopurulent discharge primarily in the middle meatus seen endoscopically and reported a mild to significant nasal NOSE score. Acute refers to complaints lasting for below 12 weeks.

Annual Illness frequencies (fallen sick or recorded sick leaves), the use of personal protective equipment (PPE) during working hours, and subjective complaints of worsening associated with working were also noted. Thus, the sample with complaints about rhinosinusitis corresponded with work referred to as occupational rhinitis. Acute rhinopharyngitis was defined as a sample with a complaint of nasal and throat inflammation and was confirmed by endoscopic findings.

Digitally recorded endoscopic otoscopy, rhinoscopy, and throat examinations were performed by otolaryngologists. The nasal floor was measured using the shaft of the endoscopic telescope. The telescope shaft was positioned adjacent to the ground, placed along the inferior meatus of either wider nasal cavity. The end lens was advanced until the posterior end of the perpendicular plate. A tape was then placed in the shaft just before the vestibulum. The length was recorded and reduced by 1 cm, given the estimated average length of the nasal vestibulum. The resulting measurement was considered the total length of the nasal floor in cm.

Mucociliary Clearance (MCC) Assessment

The MCC was measured using the saccharin transit time test: a 1-mm saccharin particle was placed on the nasal floor, 1 cm from the head of the inferior turbinate. Participants swallowed every 30–60 seconds, and the time to the first sweet taste was recorded in seconds.[14–17,19]

Vitamin D Assessment

Serum 25-hydroxyvitamin D levels were measured in venous samples analyzed at a certified clinical laboratory. Vitamin D status was categorized as normal (30 – 100 ng/mL), insufficient (21 – 29 ng/mL), or deficient (<20 ng/mL).

Confounding Variables

Other outdoor pollutants, such as PM10, ozone, nitrogen oxide (NO), carbon monoxide (CO), sulfur dioxide (SO2), and other outdoor volatile organic compounds (VOCs), were not included in this research. Indoor and other personal pollutant exposure, including active or passive smoking habits; use of household or daily cleaners, including laundry detergents, paints, air fresheners, chemical polishers, and gas appliances; exposure to mold, dust mites, pet dander, pollen, and cockroaches; and exposure to other building materials such as asbestos, was not assessed in this study. Allergic history or known diagnosis, chronic respiratory disease, and **nutritional status** were excluded from this population. Sun exposure, body surface area exposed to the sun, and total daily sunlight were not accounted for. These represent important uncontrolled confounders and are acknowledged as methodological limitations.

Data Analysis

Analyses were conducted in SPSS v29 and R v4.3. Descriptive statistics: frequencies, percentages, and means ± SD. Bivariate analyses: chi-square tests for categorical variables; independent t-tests or Mann–Whitney U tests for continuous variables. Multivariate logistic regression examined predictors of subjective rhinopharyngitis complaints; independent variables included age, sex, mask use, MCC time (s), nasal length, nasal transport speed (mm/s), vitamin D status, and PM2.5 (per 10 μg/m³). Model fit was assessed by the Hosmer–Lemeshow test; discrimination by AUC; multicollinearity by VIF.

RESULTS

Air Quality and Exposure

Table 1 presents PM2.5 data from six West Jakarta stations (August 2024): mean PM2.5 across stations = 57.58 μg/m³, mean AQI (US) = 144.71. These values exceed WHO guideline values (annual 5 μg/m³; 24-h 15 μg/m³)[23] and are comparable to levels associated with adverse respiratory outcomes.[1,3–5 The] Indonesian 24-hour standard (65 μg/m³) was also considered.[24]

Respondents' Characteristics

A total of 120 PPSU workers participated. The mean age was 40.39 ± 8.42 years. Most participants were male (90.0%), and 67.5% reported inconsistent mask use during working hours. Vitamin D insufficiency was present in 67.5%, and deficiency in 0.83% of the population. Saccharin transit time (STT) ranged from 9 to 1867 seconds (mean 427.29 ± 327.37 s). Mean nasal floor length was 64.22 ± 6.78 mm; mean mucociliary clearance velocity was 0.38 ± 0.87 mm/s. The average PM2.5 level during August 2024 ranged from 35.7 to 62.8 μg/m³, and the average AQI was 101–156. The prevalence of rhinopharyngitis was 59.2%, rhinosinusitis 8.3%, and occupational rhinitis 9.2%. Among subjects with rhinosinusitis, the prevalence of vitamin D insufficiency was 80%.

Table 1. PM 2.5 Data (August 2024).[2]

Date	Stasiun Tangkas Sports Centre, Duri Kepa, West Jakarta		Stasiun nfinitefx, Puri Indah, South Kembangan, West Jakarta		Tatalogam Tower, Duri Kepa, West Jakarta		Duitku PG, Kebon Jeruk, West Jakarta		Taman Resort Mediterania, Kapuk Muara, West Jakarta		Puretex Indonesia, Tegal Alur / Kalideres, West Jakarta		AVERAGE	
	PM2.5	AQI US	PM2.5	AQI US	PM2.5	AQI US	PM2.5	AQI US	PM2.5	AQI US	PM2.5	AQI US	PM2.5	AQI US
1	77	166	83.6	171	83.5	171	73.3	163	61.5	155	66.6	159	74.25	164.17
2	40.5	113	47.2	130	43.5	121	40	112	35.2	100	40.3	113	41.12	114.83
3	47.3	130	55.5	151	55.5	151	49.8	136	45.1	125	43.7	121	49.48	135.67
4	51.8	141	59.1	154	55.7	151	51.9	141	42.2	117	41.4	116	50.35	136.67
5	44.1	122	48.2	132	48	132	42.9	119	34.8	99	40.8	114	43.13	119.67
6	47.2	130	56.7	152	56.6	152	50.4	138	38.9	109	39.5	111	48.22	132.00
7	60	154	75.7	165	67.2	159	65.2	158	52	142	53.6	146	62.28	154.00
8	61.5	155	72.5	163	67.3	159	61	155	53.1	144	51.3	140	61.12	152.67
9	40.5	113	50.6	138	46.2	127	46	127	43.2	120	43.4	120	44.98	124.17
10	51.9	141	58.8	153	54	147	51.6	141	39.7	111	40.8	114	49.47	134.50
11	50.7	138	61.8	155	55.5	151	50.7	138	37.9	107	41.4	116	49.67	134.17
12	47	129	60.4	154	58.3	153	53.7	146	44.2	122	44.5	123	51.35	137.83
13	50	137	64.3	157	61.8	155	61.3	155	53	144	49.4	135	56.63	147.17
14	58.2	153	66.4	159	60.2	154	57.5	152	56.3	152	60.4	154	59.83	154.00
15	60	154	68.7	160	65.5	158	59.8	154	53	144	53.6	146	60.10	152.67
16	63.5	157	80	168	71.8	162	66.8	159	57.7	153	55.4	150	65.87	158.17
17	55.5	151	72.5	163	65.7	158	61.1	155	49.3	135	48.7	134	58.80	149.33
18	51	139	63.8	157	57.2	152	55.3	150	45.2	125	43.3	120	52.63	140.50
19	61.8	155	84.8	172	70.3	161	69.9	161	60.3	154	62.8	156	68.32	159.83
20	70.2	161	97	180	81.5	169	81.3	169	59.2	154	79.8	168	78.17	166.83
21	62.4	156	70.7	162	67.6	159	62	156	53.4	145	56	151	62.02	154.83
22	38.2	108	42	117	42.9	119	38.9	109	35.5	101	35.7	101	38.87	109.17
23	61.8	155	72.7	163	66.1	158	61.5	155	49.8	136	61.5	155	62.23	153.67
24	78.5	167	88.3	174	81.7	169	77.5	166	62.3	156	64.4	157	75.45	164.83
25	43	119	61.7	155	53.5	145	53.9	146	42.6	118	41.6	116	49.38	133.17
26	74.5	164	85.6	172	77.9	167	72.6	163	67	159	69.5	161	74.52	164.33
27	56	151	59.5	154	58.5	153	51.3	140	53.6	146	54	147	55.48	148.50
28	60.9	155	78.7	167	64.4	157	63.3	156	49.6	136	72.8	163	64.95	155.67
29	74.4	164	89.1	175	85.5	172	77.8	167	67.2	159	79.3	168	78.88	167.50
30	45.9	127	60	154	53	144	50.2	137	47.1	130	51.5	140	51.28	138.67
31	40.9	114	58.9	153	46.3	128	48.3	133	40.3	113	43.1	120	46.30	126.83
Rerata	55.68	142.55	67.57	157.42	62.02	152.06	58.28	147.00	49.36	132.61	52.58	136.61	57.58	144.71

Notes: PM2.5 levels (μg/m³)

Bivariate Analysis

Tables 2 and 3 show associations between characteristics and rhinopharyngitis and occupational rhinitis. None of the examined categorical variables (sex, age group, mask use, vitamin D status) showed significant bivariate associations with rhinopharyngitis (all $p > 0.05$). Similarly, no significant associations were observed for occupational rhinitis.

Table 2. Association Between Respondents' Characteristics and Rhinopharyngitis

Variable	Rhinopharyngitis		p-value
	No (n (%))	Yes (n (%))	
Sex			
Male	83(76.9%)	25(23.1%)	0.481#
Female	8(66.7%)	4(33.3%)	
Age			
20-40 years	42(72.4%)	16(27.6%)	0.309C
41-60 years	49(80.3%)	12(19.7%)	
Mask Use at Work			
Tidak	59(72.8%)	22(27.2%)	0.270C
Ya	32(82.1%)	7(17.9%)	
Serum Vitamin D3 25-OH levels			
Normal	30(76.9%)	9(23.1%)	0.368C
Insufifciency	46(71.9%)	18(28.1%)	
Deficiency	15(88.2%)	2(11.8%)	
Legend: n = frequency; % = percentage; C = Chi-square test; # = Fisher's Exact test			

Table 3. Association Between Respondents' Characteristics and Work-Related Rhinitis (Occupational Rhinitis)

Variable	Work-Related Rhinitis		p-value
	No (n (%))	Yes (n (%)	
Sex			
Male	98(90.7%)	10(9.3%)	1.000#
Female	11(91.7%)	1(8.3%)	
Age			
20-40 years	51(86.4%)	8(13.6%)	0.101C
41-60 years	48(95.1%)	3(4.9%)	
Mask Use at Work			
Tidak	76(93.8%)	5(6.2%)	0.173#
Ya	33(84.6%)	6(15.4%)	
Serum Vitamin D3 25-OH levels			
Normal	37(94.9%)	2(5.1%)	0.500#
Insufifciency - Deficiency	72(88.9%)	9(11.1%)	
Legend: n= frequency; %=percentage C= Chi-square test; #=*Fisher's Exact test*			

Multivariate Logistic Regression Analysis

A multivariate logistic regression model was developed to examine the simultaneous effects of demographic characteristics, mucociliary clearance function, vitamin D status, nasal anatomical variables, and short-term PM2.5 exposure on the likelihood of subjective rhinopharyngitis. Variables with theoretical relevance and those with $p < 0.25$ in bivariate analysis were included in the adjusted model.

Model Results

Table 4 presents the adjusted odds ratios (AOR), 95% confidence intervals (CI), and corresponding p-values. None of the predictors reached statistical significance, indicating that no single factor independently explained the occurrence of subjective rhinopharyngitis after adjusting for confounders. However, several trends were observed.

Tabel 4. Adjusted Odds Ratios for Predictors of Subjective Rhinopharyngitis

Variable	OR	95% CI	p-value
Age (per year)	.98	0.92–1.03	0.369
Female sex	.87	0.74–20.07	0.108
MCC time (per second)	.001	1.000–1.002	0.187
Mask use	.56	0.20–1.51	0.249
Vit D insufficiency vs normal	.01	0.37–2.72	0.992
Vit D deficiency vs normal	.18	0.02–1.38	0.099
Nasal length (per mm)	.97	0.90–1.03	0.299
Mucociliary clearance velocity (mm/s)	.06	0.65–1.73	0.821
PM2.5 per 10 μg/m³	**.69**	**0.15–49.56**	**0.507**

Although none of the variables were statistically significant, several clinically meaningful patterns emerged. Female sex was associated with higher adjusted odds of reporting rhinopharyngitis (AOR 3.87), suggesting possible sex-based susceptibility, though the confidence intervals were wide due to the small female sample size. Longer MCC time showed a trend toward increased risk (AOR 1.001), supporting the physiological plausibility that impaired mucociliary clearance may predispose to upper airway infection. Vitamin D deficiency appeared protective in the adjusted model (AOR 0.18), though this counterintuitive result likely reflects the sample distribution rather than a true biological effect. Higher short-term PM2.5 exposure was associated with increased odds of symptoms (AOR 2.69), but the CIs were extremely wide due to limited daily variation across the study period.

Overall, the multivariate model indicates that subjective rhinopharyngitis among PPSU workers likely results from a multifactorial interplay rather than a single dominant predictor. Larger studies with broader exposure ranges and additional confounding variables (e.g., smoking history, allergy status, chronic illness, dietary factors) may better clarify these relationships.

DISCUSSION

This study's analysis detected no statistically significant associations between short-term PM2.5 exposure, MCC, vitamin D status, or demographic characteristics and rhinosinusitis, rhinopharyngitis, or occupational rhinitis. Despite PM2.5 levels during the sampling period exceeding WHO-recommended limits, reaching 35.7–62.8 μg/m³, they were comparable to pollution levels associated with adverse respiratory outcomes in previous research.[1,23] These findings highlight the complexity of upper respiratory disease pathogenesis and suggest that ENT morbidity cannot be explained by a single environmental or physiological factor alone.

Previous studies have shown that air pollution, particularly PM2.5, contributes to upper respiratory tract inflammation, allergic rhinitis, asthma, and otitis media.[3,7-10] Proposed biological mechanisms include epithelial damage, impaired mucociliary function, altered mucin composition, and dysregulated mucosal immunity.[14-18] Urban PM2.5 has been shown to induce mucociliary remodeling at the genomic level, reducing epithelial resilience and altering innate immune responses.[15] Moreover, the chemical composition of particulates can exacerbate toxic effects on the mucociliary epithelium.[16] Although these mechanisms suggest a plausible link between pollution and ENT symptoms, the present study's null findings likely reflect methodological and analytical limitations rather than the absence of a biological relationship.

Mucociliary clearance times in this study showed considerable variability, ranging from 9 to 1867 seconds. Although some respondents demonstrated prolonged clearance, the mean MCC remained broadly within the ranges reported in healthy individuals.[14] The saccharin transit test, while widely used, lacks sensitivity to detect mild or chronic mucociliary dysfunction and may underestimate mucociliary impairment induced by prolonged particulate exposure.[19, 21] Technical faults may also contribute to the wide range, particularly when the sample inhales the saccharin particle rather than it traveling through the nasal mucus blanket. Technique execution should be a concern. Subject's position, the manner of saccharin particle introduction, saccharin particle size, and guidance to the sample subject may influence the result. Mucociliary transport may be influenced by age, nasal septal deviation, smoking habit, physical activity in daily life, alcohol or caffeine consumption, use of drugs that may affect MCC, circadian cycle, and environmental conditions. Anticholinergics, aspirin, anesthetics, and benzodiazepines may decrease MCC. Chronic rhinosinusitis medications such as cholinergics, methylxanthines, anti-asthmatics, antibiotics (penicillin, cephalosporin, and sulphonamide), surfactant, hypertonic saline solution, and water aerosol may improve MCC.[21]

Rodrigues et al.[21] suggested performing the test in a seated position in a quiet room, with a room temperature of 25°C, humidity of 50–60%, and air conditioning and a humidifier recommended to control the examination room environment. Subjects were asked to abstain from alcohol, caffeine, cigarettes, and drugs for at least 12 hours prior to evaluation. No strenuous physical activity was allowed 24 hours before the examination. A plastic straw was trimmed to facilitate deposition of saccharin particles within the nose. The amount of saccharin particles was standardized at 2.5 µg, rather than by the diameter or size of the saccharin. The subject's head position was slightly extended, approximately 10° of neck extension. The saccharin particle was placed 2 cm into the inferior turbinate. Subjects were asked not to get up, talk, cough, sneeze, or in any way manipulate their nose. If this occurred, the test was rescheduled for another day. The expected flavor and nature of the substance were not disclosed to the subject to prevent false positives. [21]

The mean saccharin transit time (STT) in this study was 427.29 ± 327.37 s (≈ 7.12 ± 5.46 minutes). The normal average mucociliary transit time is 12 – 15 minutes; more than 20 minutes is considered prolonged and indicates a disturbance in the MCC.[14] Resmi et al. found the average STT in wood factory workers was 18.22 ± 3.874 minutes.[20] Priscilla et al. found a higher STT in adult women exposed to biomass fuel than in adult women who used clean fuel.[21] Ferreira Ceccato et al. did not find a difference in STT between smokers and nonsmokers among sugarcane cutters.[21] The significantly lower mean STT in this study was due to a technical fault. The technique of depositing saccharin particles, along with subject instruction to not talk during the examination, may interfere with the result, as the particles may be inhaled and carried by the nasal airflow.

Vitamin D insufficiency was present in two-thirds of respondents; deficiency was found to be less than 1%. Sowah et al. conducted a systematic review and found that combined rates of vitamin D deficiency or insufficiency were very high among indoor, outdoor, and shift workers, as well as healthcare workers, including medical residents, healthcare students, practicing physicians, nurses, and other healthcare personnel.[22] Sowah et al.[22] found that 75.2% of subjects had vitamin D insufficiency. While Goswami et al.[23] found that 40.63% of outdoor workers with type 2 diabetes mellitus in Southern West Bengal had insufficient vitamin D and 2.34% had deficient vitamin D.[23] Goswami et al. attributed their findings to sufficient duration of sun exposure during working hours and total daily sunlight.[23] While our study was conducted during August – September, which is the summer season in Jakarta, we did not account for duration of sun exposure or total daily sunlight the subjects may receive. Sowah et al.22 added that other determinants of vitamin D deficiency include culture, geography, genetics, disease states, diet, and age. No relationship was found with acute ENT symptoms in this study. This discrepancy may reflect differences in disease pathophysiology, insufficient sample size, or confounding factors such as sunlight exposure patterns, diet, and use of protective equipment among outdoor workers.

The prevalence of rhinopharyngitis in this study was 59.2%. However, the absence of statistically significant associations in the multivariate analysis highlights the multifactorial nature of ENT diseases. Teeranoraseth et al. found rhinopharyngitis to be the leading upper respiratory tract infection (URTI) causing Thai people to visit a tertiary hospital during 2017–2019. They also reported a significant correlation between PM2.5 and acute URTIs.[24] This inconsistency may be due to sample size and demographics. This study's sample consisted of outdoor workers without symptoms of URTI. The sample size was also smaller than that of Teeranoraseth. Host factors (genetic predisposition, smoking, allergic history), occupational variables (duration of exposure, type of outdoor tasks), and environmental factors (humidity, co-exposure to allergens or pathogens) may all contribute but were not assessed in this study.

Using fixed-site monitoring stations rather than personal air pollution sensors may have contributed to exposure misclassification, particularly given microenvironmental differences within urban areas. The cross-sectional design further limits causal inference because temporal relationships cannot be established. These limitations reflect common challenges in environmental epidemiology but underscore the need for more robust study designs to disentangle complex exposure–response relationships.

Strengths and Limitations

This study offers several methodological strengths, including ENT examinations performed by specialists, objective assessments of mucociliary clearance, and laboratory-confirmed vitamin D measurements. Environmental exposure was contextualized using PM2.5 data from the six nearest monitoring stations, providing reliable area-level pollution estimates consistent with WHO reporting standards.[1,25]

However, important limitations should be noted. First, the cross-sectional design precludes causal inference and limits interpretation of temporal associations. Second, pollution exposure was estimated using fixed-site monitoring stations rather than personal sensors, which may lead to exposure misclassification. Third, many key confounding variables, including other outdoor and indoor pollutants, smoking status, allergic disease history, chronic respiratory conditions, nutritional status, sun exposure, and nonoccupational pollution exposure, were not measured.[6,7,26] Fourth, the saccharin transit time test posed technical difficulties and may have insufficient sensitivity to detect mild mucociliary dysfunction, potentially attenuating measurable associations.[14,19] Finally, limited variability in PM2.5 levels during the study period and a moderate sample size reduce the statistical power to detect small effect sizes.

Implications for Practice

Despite the lack of statistically significant associations, the high prevalence of acute ENT symptoms and widespread vitamin D insufficiency among PPSU workers underscore the importance of occupational health interventions for urban outdoor workers. Routine ENT screening, training on the proper and consistent use of respiratory protective equipment, particularly N95 or equivalent masks, and workplace health education may help reduce the disease burden. Regular vitamin D screening and supplementation may be beneficial when insufficiency and/or deficiency are detected. At the public health level, strengthening environmental policies to reduce particulate emissions remains crucial, in line with WHO air quality recommendations [1,25]. Future studies with larger sample sizes, incorporating longitudinal designs, personal exposure monitoring, and comprehensive assessment of lifestyle and health-related confounders are needed to build stronger evidence and inform targeted prevention strategies.

CONCLUSION

In conclusion, although this study found no statistically significant associations between PM2.5 exposure, mucociliary clearance, vitamin D status, demographic factors, and acute ENT symptoms, the high prevalence of acute rhinopharyngitis, acute rhinosinusitis, occupational rhinitis, and vitamin D insufficiency among PPSU outdoor workers remains a concern. These null findings likely reflect methodological constraints and the complex, multifactorial nature of upper respiratory disease rather than the absence of environmental effects. Longitudinal studies with improved exposure assessment and comprehensive confounder control are needed to clarify the environmental determinants of ENT morbidity in outdoor occupational settings.

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AUTHORS CONTRIBUTION

The authors confirm their contributions to the paper as follows: study conception and design: PT, TM; data collection: TM, DA, FA; analysis and interpretation of results: PT, TM; manuscript drafting: PT, TM. All authors reviewed the results and approved the final version of the manuscript.

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CONFLICT OF INTEREST

Competing interests: No relevant disclosures.

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