Research Article

Air Quality Assessment In Wastewater Treatment Plant And Its Respiratory Effects On Workers In Al-Diwaniyah City

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Abstract

Wastewater treatment plants are essential for environmental protection, however, they can generate airborne pollutants that pose potential health risks to workers, particularly affecting the respiratory system. The study aimed to assess air quality in Al-Diwaniyah wastewater treatment plant and evaluate its respiratory effects on workers. Aim: A cross-sectional analytical study was conducted among 108 workers in the wastewater treatment plant and sewer networks. Air pollutants were measured using the Horiba PG-350 device. Respiratory symptoms were assessed using a structured questionnaire, and lung function was evaluated using spirometry. Results: All measured air pollutants (H_2S, CO_2, SO_2, NOx, CH_4, and CO) were significantly higher in the plant compared to the control area ($P < 0.01$). Respiratory symptoms were common, particularly breathlessness (52.8%), dry cough (49.1%), and chest tightness (40.7%). Spirometry results indicated reduced lung function, with mean FEV1 (1.87 ± 0.72) and FEV1/FVC ratio (58.16 ± 16.25).), suggesting an obstructive pattern. Conclusion: Occupational exposure in the wastewater treatment plant is associated with elevated levels of air pollutants, increased prevalence of work-related respiratory symptoms, and impaired lung function among workers.

Keywords: Air quality, wastewater treatment plant, occupational exposure, respiratory symptoms, spirometry.

1. Introduction

Air is a vital component of the environment, and altering its quality may have detrimental impacts on ecosystems while also having an influence on human health due to the air's ability to swiftly carry specific levels of contaminants [1].Wastewater treatment facilities, or WWTPs, are crucial for processing and purifying wastewater before releasing it into the environment [2]. these facilities are essential for cleaning wastewater and reducing residential and industrial pollution in freshwater reserves worldwide [3].Wastewater is generated by residential, commercial, industrial, and institutional activities. It comprises biological, chemical, and physical contaminants that have a major detrimental impact on the environment and have the capacity to permanently damage ecosystems and destroy numerous habitats [4].wastewater treatment facilities generate a number of pollutants that might degrade the quality of the air. So, Air quality laws, such as threshold limits for air pollutants and monitoring, maintaining, and even improving the air quality, are of great interest in order to protect human health and the environment [5]. Workers at WWTP are subjected to many potential hazards related to their occupational health since they deal with machinery, mechanical equipment, and a lot of hazardous chemicals when treating wastewater [6].During treatment processes, a range of gases are emitted. Grit tanks are regarded as a source of nitrous oxide (N_2O) in preliminary treatment (Vergelli et al., 2024), whereas emissions from primary, secondary, and sludge treatment include hydrogen sulfide (H_2S), methane (CH_4), N_2O, ammonia (NH_3), and carbon dioxide (CO_2) (Pro et al., 2025). Additionally, ozone (O_3), chlorine dioxide (ClO_2), and chlorine (Cl_2) are utilized in tertiary stage disinfection. The health of plant workers may be impacted by certain components, even at low concentrations [7]. Since workers spend a significant amount of time at work, sometimes in cramped areas where exposure to indoor pollutants may be higher than outside levels, the importance of air quality in the workplace cannot be overstated [8].

2. Methodology

2.1 Study Design and Setting

A cross-sectional analytical study was conducted to assess air quality and its respiratory effects among workers. The study was carried out at Al-Diwaniyah wastewater treatment plant, Iraq. The city of Al-Diwaniyah is located in the south-mid part of Iraq and this plant is located on road 8 in the southern part of Al-Diwaniya city on Shut Al-Diwaniya.

2. 2 Sample Size

The Study was conducted among 108 workers in Al Diwaniyah wastewater treatment plant and sewer networks including all departments and functional area, all of them had a lung function test with spirometer device. Since the study population was finite and specific, the sample size was determined using the Cochran Formula for Finite Populations[9]. This ensures that the sample is representative of the total workforce. The calculation was based on a total population (N) of 150 employees in the station and sewer networks. With an initial sample size for an infinite population (n_0) of 384 (based on Z=1.96, P=0.5, and d=0.05), a final sample size of 108 participants was selected to achieve a 95% confidence level with a 5% margin of error.

Inclusion Criteria

Encompassed workers aged ≥23 years of both sexes who provided verbal consent and free of malignant diseases from all departments, were included.

Exclusion Criteria

workers who provided incomplete questionnaire data or declined participation, those diagnosed with malignant diseases, and individuals under 23 years of age were excluded from the study. Respondents were chosen using convenient sampling via direct interviews.

2.3 Variables

Following the standard analytical framework for occupational health studies, occupational exposure to hazardous gases (H_2S, CO_2, SO_2, NO_x, CH_4, and CO) was the primary independent variable. Respiratory health outcomes, including symptoms (breathlessness, cough, chest tightness) and spirometric parameters (FVC, FEV_1, FEV_1/FVC), were defined as the dependent variables. Socio-demographic factors such as age, gender, BMI, and smoking status were included as covariates.

2.4 Data Collection

Data were collected through interviews with workers by using a structured questionnaire filled by the researcher and questions asked using a clear Arabic language. employer's data were entered into the questionnaire using the English language The questionnaire filling takes about 15-20 minutes. Lung function indicators were obtained by performing spirometer tests on the employees using a portable spirometer device. Diagnosis of lung diseases was made by doctors specialized in chest and respiratory diseases at Al-Diwaniyah Teaching Hospital, based on the spirometer-derived percentages. Concentrations of toxic gases in the air were determined by collecting air samples from different areas and analyzing them using Real-time Gas Analyzer (Horiba PG-350 device). Data collection occurred over approximately three months, from 28 December /2025 to 24 March /2026

2.5 Statistical Analysis

The collected data were coded, entered, presented, and analyzed by computer using the available data base software program statistical package of IBM SPSS-29 (IBM Statistical Packages for Social Sciences- version 29, Chicago, IL, USA). Data were presented in simple measures of frequency, percentage, mean, standard deviation, and range (minimum-maximum values). The significance of difference of different means (quantitative data) were tested using Students-t-test for difference between two independent means or Paired-t-test for difference of paired observations (or two dependent means), or ANOVA test for difference among more than two independent means

2.6 Ethical Considerations

One of the most important measures taken by the researcher is ethical considerations. Ethical approval was gained from the Middle Technical University/ Medical Ethics Committee with the reference number (MEC: 183). Protecting the values and dignity of participants is one of the most basic principles before collecting data.

3 Results

One hundred eight workers (108) participated in this study. the largest proportion of participants fell within the 30–39 age group (41.7%) while, the smallest percentage was observed in the under 30 age group (10.2%). The participants' ages ranged from 23 to 59 years, with a mean age of 40.1 \pm 8.7 years. Regarding gender and marital status, the majority of the participants were male (60.2%) and the huge majority were married (89.8%) while, only 7.4% were single. In terms of Body Mass Index (BMI), the results show that 38.0% of the participants were overweight followed by 25.9% in the Obese I category while only 24.1% maintained a normal BMI. The mean BMI for the sample was 28.93 \pm 5.12 kg/m^2. Regarding smoking status, 32.4% were smokers, while 67.6% were non-smokers. Exposure to passive smoking was reported by 68.5% of the participants.

Table (1): Occupational characteristics and exposure conditions among wastewater treatment plant workers in Al-Diwaniyah city

		No.	%
Age (years)	<30years	11	10.2
	30---39	45	41.7
	40---49	34	31.5
	50---59years	18	16.7
	Mean ±SD (Range)	40.1±8.7	(23-59)
Gender	Male	65	60.2
	Female	43	39.8
Marital status	Single	97	89.8
	Married	8	7.4
	Separated	3	2.8
BMI (Kg/m2)	Normal (18.5-24.9)	26	24.1
	Overweight (25-29.9)	41	38.0
	Obese I (30-34.9)	28	25.9
	Obese II (=>35)	13	12.0
	BMI (Kg/m2)	28.93±5.12	(18.69-39.84)
	Height (cm)	164.88±8.18	(149-188)
	Weight (Kg)	78.44±13.77	(50-110)
Smoking	Yes	35	32.4
	No	73	67.6
Duration of smoking	<1year	1	2.9
	1---2	4	11.4
	3---4	3	8.6
	=>5years	27	77.1
Passive smoker	Yes	74	68.5
	No	34	31.5

Duration of passive smoking	<1year	4	5.4
	1---2	12	16.2
	3---4	6	8.1
	=>5years	52	70.3

The wastewater treatment facility had much higher air pollution concentrations than the control region. Of all the gases examined, hydrogen sulfide (H2S) exhibited the greatest relative increase, rising to 9.669 ± 1.244 ppm in the plant and 1.375 ± 0.385 ppm in the control region. Additionally, there was a significant increase in carbon dioxide (CO_2) and methane (CH_4), with CO_2 rising to 955.1 ± 80.8 ppm from 594.3 ± 22.8 ppm and CH_4 rising to 4.151 ± 0.742 ppm from 0.042 ± 0.032 ppm in the control. Furthermore, the plant environment showed steady increases in nitrogen oxides (NOx) and sulfur dioxide (SO_2), suggesting a widespread rise in gaseous pollutants. Although less noticeable than H_2S and CH_4, carbon monoxide (CO) levels were considerably higher in the plant (3.65 ± 0.23 ppm) than in the control region (1.04 ± 0.18 ppm). The pattern was further reinforced by particulate matter measurements, which showed significantly higher PM10 and PM2.5 values in the factory, indicating greater exposure to airborne particulates. Overall, hydrogen sulfide emerged as the dominant pollutant in the plant environment, followed by methane and carbon dioxide, highlighting a mixed exposure profile of both toxic and asphyxiant gases. All observed differences were statistically highly significant ($P < 0.01$).

Table (2): Comparison of air pollutant concentrations between the control (agricultural) area outside the wastewater treatment plant and Al-Diwaniyah main sewage treatment plant (emergency channel), Al-Diwaniyah city

By Horiba PG_350 device	Control /Agricultural area (outside the plant)			Al Diwaniyah main sewage treatment plant/ Emergency channel			P value
	Mean ±SD	Median	(Range)	Mean ±SD	Median	(Range)	
NO (ppm)	0.0006±0.0011	0.0001	(0-0.003)	0.1010±0.0142	0.1030	(0.072-0.114)	<0.001
NO2 (ppm)	0.034±0.064	0.011	(0.007-0.180)	0.130±0.004	0.129	(0.123-0.137)	0.002
NOX (ppm)	0.024±0.004	0.023	(0.020-0.030)	0.178±0.004	0.177	(0.172-0.183)	<0.001
SO2 (ppm)	0.037±0.004	0.036	(0.033-0.042)	0.229±0.017	0.235	(0.203-0.250)	<0.001
H2S (ppm)	1.375±0.385	1.372	(1.030-2.120)	9.669±1.244	9.600	(8.250-12.00)	<0.001
CO2 (ppm)	594.3±22.8	592.8	(569-631)	955.1±80.8	929	(899-1136)	<0.001
CH4 (ppm)	0.042±0.032	0.042	(0.000-0.100)	4.151±0.742	4.163	(2.975-5.119)	<0.001
CO (ppm)	1.04±0.18	1.01	(0.90-1.40)	3.65±0.23	3.64	(3.39-4.10)	<0.001
Temperature (℃)	34.40±0.23	34.35	(34.20-34.80)	38.26±0.16	38.23	(38.10-38.50)	<0.001
Wind Dir.	118.0±0.6	118.0	(117.0-119.0)	142.2±1.6	141.5	(141.0-145.0)	<0.001
Wind Speed (m/s)	1.70±0.11	1.70	(1.50-1.80)	2.40±0.15	2.45	(2.10-2.50)	<0.001

PM 10 /falling dust (Mm)	83±			237±			
PM 2.5 /falling dust (Mm) 141± /falling dust(Mm)	56±			141±			

In terms of the type of exposure at work, 55.6% of the participants were categorized as exposed (blue collar), while 44.4% were defined as partially exposed (white collar). With a mean duration of 10.7 \pm 7.3 years (range: 3 months to 40 years), the majority of participants (40.7%) had been working for five to nine years. The majority of participants (68.5%) worked five days a week, and 76.9% reported working eight hours a day. Additionally, a fixed (day) shift system was used by 88.0% of the sample. In terms of health and safety precautions, only a very little fraction (0.9%) got routine examinations while working, whereas 50.0% had an assessment prior to beginning their present employment, mostly eye exams (79.6%). Furthermore, 25.0% of the employers said they had received occupational safety training. Furthermore, just 11.1% of individuals said they had a second job, although 79.6% said their health had gotten worse since beginning the employment. The results also show that 56.5% of the participants worked indoors and 43.5% worked outside. Concerning the availability of sufficient ventilation in the workplace, in terms of the ability to smell sewage odor after working for a while, the majority of participants (79.6%) reported that there was no adequate ventilation, followed by those who reported that ventilation was sometimes adequate (13.9%), and only a small percentage indicated that adequate ventilation was available (6.5%). The majority of participants (63.0%) reported losing the ability to smell the odor after some time, while 37.0% said they could smell it continuously.

Table (3): Occupational characteristics and exposure conditions among wastewater treatment plant workers in Al-Diwaniyah city

		No.	**%**
Work exposure nature	Exposed (Blue collar)	60	55.6
	Partially exposed (White collar)	48	44.4
Duration of present work	<1year	6	5.6
	1---4	13	12.0
	5---9	44	40.7
	10---14	10	9.3
	15---19	21	19.4
	=>20years	14	13.0
	Mean ±SD (Range)	10.7±7.3	(3M-40Y)
Number of days/ week	3	5	4.6
	4	10	9.3
	5	74	68.5
	6	3	2.8

	7	16	14.8
Number of hours/ day	6	11	10.2
	7	14	13.0
	8	83	76.9
Shift system of work	Fixed (Day)	95	88.0
	Rotating (Day/Night)	13	12.0
Have a second job		12	11.1
Had an Examination before starting this job		54	50.0
Type of examination	Ocular exam	43	79.6
	Full exam	11	20.4
Have regular checkup during the work		1	0.9
Had health worsen since you start the job		86	79.6
Have any training regard occupational safety		27	25.0
Work place	Indoor	61	56.5
	Outdoor	47	43.5
Have an adequate ventilation in work place	Yes	7	6.5
	No	86	79.6
	Sometimes	15	13.9
Feel losing ability to smell the sewage odor after staying in the work for a while	Yes (stop smelling after a while)	68	63.0
	No (smell it all the time)	40	37.0

The most common symptom, reported by 52.8% of participants, was breathing problems, which was followed by followed by dry cough (49.1%) and chest tightness (40.7%). A large proportion of the sample also reported other symptoms like nasal irritation (38.9%), wheezing (38.0%), cough with sputum (37.0%), sinus problems (33.3%), and throat irritation (32.4%). One important finding in this table is the high percentage of symptoms that specifically occur during work hours. Among those who experienced symptoms, most reported that such symptoms manifest during work, with the highest rates reported for throat irritation (97.1%), chest tightness (93.2%), nasal irritation (92.9%), and sinus trouble (91.7%). Additionally, 91.2% of participants who experienced breathlessness, 87.8% who experienced wheezing, 84.9% who experienced a dry cough, and 77.5% who experienced a cough with sputum confirmed that these symptoms occurred during their work period. The results also show that 13.0% of participants felt their symptoms got worse on Sunday, the first day of the working week, compared to other days. In addition, 61.1% of the participants stated that they wash their hands with soap and water before eating during work hours. Among those who experienced symptoms, a vast majority reported that these issues manifest during work.

Table (4): Distribution of respiratory symptoms and their occurrence during working hours among wastewater treatment plant workers in Al-Diwaniyah city

Current Respiratory Symptoms	Experienced Symptoms				Symptoms during work			
	Yes		**No**		**Yes**		No	
	No.	%	No.	%	No.	%	No.	%
Suffer from a dry cough	53	49.1	55	50.9	45	84.9	8	15.1
Have cough with sputum	40	37.0	68	63.0	31	77.5	9	22.5
Wheezing of chest	41	38.0	67	62.0	36	87.8	5	12.2
Chest tightness	44	40.7	64	59.3	41	93.2	3	6.8
Breathlessness	57	52.8	51	47.2	52	91.2	5	8.8
Nasal irritation	42	38.9	66	61.1	39	92.9	3	7.1
Throat irritation	35	32.4	73	67.6	34	97.1	1	2.9
Sinuses trouble	36	33.3	72	66.7	33	91.7	3	8.3
Feel that the symptoms become worse in first day of working (Sunday) than another days	14	13.0	94	87.0				
Clean your hands with water and soap before eating in the work	66	61.1	42	38.9				

Regarding the measured lung volumes, the mean Forced Vital Capacity (FVC) was 3.20 \pm 0.80 (Range: 1.29-5.37), while the Forced Expiratory Volume in the first second (FEV1) showed a mean of 1.87 \pm 0.72. As a result, the Peak Expiratory Flow (PEF) had a mean of 2.37 \pm 1.17 and the FEV1/FVC ratio was 58.16 \pm 16.25. Additionally, the mean projected FVC was 4.12 \pm 0.55 and the expected FEV1 was 3.43 \pm 0.46 when the actual data were compared to the anticipated values. The predicted PEF and FEV1/FVC ratio had averages of 8.51 \pm 0.73 and 79.99 \pm 1.66, respectively. In order to give a more accurate clinical picture, the table also shows the proportion of expected values. While the mean predicted FEV1 (%) was much lower at 53.99 \pm 18.40, the mean predicted FVC (%) was 77.21 \pm 14.15. Furthermore, the Predicted PEF (%) had the lowest percentage, with a mean of 27.37 \pm 11.97, whereas the mean Predicted FEV1/FVC (%) was 71.74 \pm 19.49. When compared to the individuals' expected normal levels, these data show a significant decrease in the majority of respiratory indexes

Table (5): Spirometry parameters of wastewater treatment plant workers in Al-Diwaniyah city

	Mean ±SD (Range)	**[Median]**
FVC	3.20±0.80 (1.29-5.37)	[3.19]
FEV1	1.87±0.72 (0.38-3.87)	[1.88]
FEV1/FVC	58.16±16.25 (16.94-88.17)	[59.72]
PEF	2.37±1.17 (0.52-7.28)	[2.24]

Predicted FVC	4.12±0.55 (3.08-5.71)	[4.06]
Predicted FEV1	3.43±0.46 (2.40-4.72)	[3.39]
Predicted FEV1/FVC	79.99±1.66 (73.53-83.09)	[80.28]
Predicted PEF	8.51±0.73 (5.21-10.4)	[8.48]
Predicted FVC (%)	77.21±14.15 (33-100)	[78]
Predicted FEV1 (%)	53.99±18.40 (11-96)	[55]
Predicted FEV1/FVC (%)	71.74±19.49 (21-100)	[72]
Predicted PEF (%)	27.37±11.97 (6-68)	[26]

5. Discussion

The results of our study showed a significant disparity between the air quality of the outdoor working environment represented by emergency channel and the indoor environment that represented by station staff Room. Overall, the concentrations of all measured pollutants were markedly higher in the outdoor areas, shows a potentially higher occupational risk to field workers compared to administrative staff. Regarding Hydrogen Sulfide and Methane, the current finding showed that the mean concentration of H2S outdoors was 9.669 ppm, significantly exceeding the indoor level of 5.361 ppm. These findings align perfectly with Toledo [10] which documented that H_2S levels within WWTPs can reach up to 14.7 ppm depending on plant configuration and wastewater temperature. The higher level of outdoor H2S may be attributed to the microbial decomposition of organic matter under anaerobic conditions; the open nature of the emergency channels facilitates the rapid volatilization of this gas into the ambient air. At the same time, outdoor CH4 concentrations reached 4.151 ppm, whereas indoor levels remained low at 0.874 ppm. This trend is consistent with Song [11], which found that CH_4 emissions are frequently very high in open systems due to the emulative nature of the gas, where physical flow acts as a stripping mechanism that actively releases dissolved methane into the workers' breathing zone. Regarding Carbon Dioxide and Carbon Monoxide, the study recorded an exceptionally high outdoor CO2 concentration of 955.1 ppm compared to 714.1 ppm indoors. This massive emission matches the mechanisms that mentioned by Anazonwu and Fahmi [12], who reported high CO2 discharge caused by aerobic digestion processes. This is explained by the vigorous aerobic breakdown of organic loads in the open channels, releasing biogenic CO2 directly into the atmosphere. In contrast, the outdoor CO level reached 3.65 ppm, which is higher than the 0.77 ppm recorded indoors. Interestingly, these figures are significantly higher than the average measurements reported by Viteri [3] who recorded approximately 0.25 ppm in similar settings. This discrepancy suggests that the elevated CO levels in the current study area are likely affected by abiotic external sources, such as combustion exhaust from heavy diesel machinery and generators operating near the channels. Regarding Particulate Matter PM10 and PM2.5, Outdoor suspended particulates were very high PM10: 237 \mu g/m^3, PM2.5: 141 \mu g/m^3) compared to indoor levels. This trend strongly agree with the findings of Vishwakarma [13] who demonstrated that mechanical agitation at WWTP inlets forcefully aerosolizes solid particles. The scientific justification for this lies in the mechanical turbulence and bubble bursting at the wastewater surface in the open channels, which propels biological debris and bio aerosols directly into the outdoor air, significantly increasing the particulate load. Regarding Nitrogen Oxides and Sulfur Dioxide, the outdoor area recorded NOx at 0.178 ppm and SO_2 at 0.229 ppm, both outperforming indoor levels and exceeding the ambient concentrations reported by Viteri [3](0.021 ppm and 0.003 ppm, respectively). While NO can be produced biologically, the highly elevated levels of both NOx and SO2 in this facility point toward an additive effect from localized combustion engines. Furthermore, this suggests a lack of advanced chemical air-washing or scrubbing systems in the plant, which are typically designed to neutralize these compounds before they reach the workers' breathing zones. Regarding experienced symptoms among the study participants and their occurrence during work hours in. The most common symptom, reported by 52.8% of participants, was breathing problems, which was followed by followed by dry cough (49.1%) and chest tightness (40.7%). A large proportion of the sample also reported other symptoms like nasal irritation (38.9%), wheezing (38.0%), cough with sputum (37.0%), sinus problems (33.3%), and throat irritation (32.4%). This finding consistent with Ahmed and Balkhyour [14], stated that impact of occupational exposures on respiratory health and lung function deterioration in mechanics and worker. Who are exposed are particularly susceptible to pulmonary function impairment and respiratory health problems. Chest tightness and whistling were the most often reported respiratory symptoms in the exposed group, although the reported usage of masks for airway protection was extremely low, Men are more likely than women to experience airflow obstruction, respiratory discomfort, emphysema, and gas trapping as a result of occupational dust and fume exposure women [15].

One important finding in this table is the high percentage of symptoms that specifically occur during work hours. Among those who experienced symptoms, most reported that such symptoms manifest during work, with the highest rates reported for throat irritation (97.1%), chest tightness (93.2%), nasal irritation (92.9%), and sinus trouble (91.7%). This finding in line with study which demonstrated that even in settings with exposure levels below the existing occupational exposure limit for oil mists, machine workers report elevated symptoms of asthma, wheezing, coughing, and nose and throat problems depending on time of working in occupation a site [16]. Furthermore, study demonstrated that short-term exposure to fine particles at work and in the environment is linked to lower FEV1 and FVC in healthy persons. For a comparable exposure increment, occupational studies had a lower meta-estimate than environmental studies; nevertheless, occupational studies had much higher exposure levels. This might indicate a possibly nonlinear association with a steeper slope at lower concentrations between PM exposure and certain lung function markers [17]. From Researcher Opinion odor ventilation adequacy was limited (most workers reported poor ventilation), and industrial odor exposure has been associated in the literature with increased upper respiratory complaints. While odor itself is not the only hazard in WWTPs, it often co-occurs with chemical irritants, and systematic evidence links odor-related exposures to respiratory symptom patterns. Regarding respiratory function parameters (spirometry) showed impairment relative to predicted values this pattern is clinically meaningful because FEV_1 and FEV/ FVC are frequently decreased in obstructive airway processes, whereas PEF may indicate airflow restriction and peak expiratory constriction. This finding consistent with study conducted in china that stated, A PM2.5 concentrations of 35.66 µg/m3 was strongly correlated with FVC, FEV1, and FEV1/FVC, with unadjusted hazard ratios of -0.06 (95% confidence range, -0.10 to -0.01), -0.13 (-0.17 to -0.10), and -22.10 (-24.62 to -19.26), respectively, long-term exposure to elevated ambient PM2.5 concentrations is linked to a decrease in lung function [18]. Furthermore, short-term exposure to fine particles in the environment and at work is linked to lower FEV1 and FVC in healthy people. For a comparable exposure increment, occupational studies had a lower meta-estimate than environmental studies; nevertheless, occupational studies' exposure levels were much higher [17].

Limitations

This study has some limitations. The cross-sectional design limits causal inference. The sample was limited to workers from a single wastewater treatment plant, which may affect generalizability. In addition, some variables such as smoking status and age were not fully controlled, which may have influenced the results. Data based on self-reported questionnaires may also be subject to recall bias.

Conclusion

The concentrations of many gaseous contaminants in the wastewater treatment facility were much higher, and the levels of reparable. The overall pattern of pollutants, especially the high concentrations of hydrogen sulfide, supports the possibility of mixed chemical and particle exposure

Competing Interests

The authors declare no competing interests.

Authors Contribution

Za. Ri: Conceptualization of the study, literature search, data collection, and statistical analysis.
Lu. Hu: manuscript writing and editing, contributed to the conceptualization of the study.
Is. Ja. assisted in data collection and analysis, participated in drafting and revising the manuscript, provided critical feedback throughout the research process and helped shape the final version of the article.
All authors equally contribute to this study.

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