



Respiratory Disorders Associated with Occupational Inhalational Exposure to Bio-aerosols among Wastewater Treatment Workers of Petrochemical Complexes

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Abstract

Background: Workers in wastewater treatment plants are exposed to a wide range of chemicals as well as biological contaminants.

Objective: To ascertain whether exposure to bio-aerosols under the normal working conditions in wastewater treatment plants is associated with any significant changes in the prevalence of respiratory symptoms and lung function capacities.

Methods: 198 employees of wastewater treatment plants and 99 unexposed persons were studied. American thoracic society (ATS) standard respiratory symptom questionnaire was used to determine the prevalence of respiratory symptoms. Pulmonary function tests were conducted for each participant.

Results: The prevalence of respiratory symptoms among exposed persons was significantly higher than that of unexposed people. Mean values of most pulmonary function test parameters were significantly lower in the exposed compared to the comparison group persons.

Conclusion: Increased prevalence of respiratory symptoms and decrements in pulmonary function test parameters may be attributed to exposure to bio-aerosols released from wastewater treatment plants.

Keywords: Waste water; Environmental pollution; Respiration disorders; Respiratory function tests; Aerosols

Introduction

Wastewater treatment workers are exposed to a wide range of chemical pollutants and biological contaminants such as bacteria and

fungi resulting in an increased risk for respiratory disorders.¹⁻³ Respiratory disorders and lung function impairments are the main health effects of exposure to bio-aerosols.⁴ For instance, Friis, *et al*, in their study demonstrated that respiratory in-

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Received: May 30, 2014
Accepted: Aug 31, 2014

Cite this article as: Jahangiri M, Neghab M, Nasiri G, *et al*. Respiratory disorders associated with occupational inhalational exposure to bio-aerosols among wastewater treatment workers of petrochemical complexes. *Int J Occup Environ Med* 2015;6:41-49.

For more information on the work-related health effects among wastewater treatment plants workers see <http://www.theijoem.com/ijoem/index.php/ijoem/article/view/104>



flammation and irritations in wastewater treatment workers are the result of their exposure to microbial agents.⁵ Furthermore, Nethercott and Holness carried out a health investigation on 50 wastewater treatment plant workers in Toronto, Canada.⁶ The workers had symptoms of fatigue (50%), skin problems (46%), throat irritation (42%), productive cough (38%), stomach problems (38%), chronic bronchitis (36%), wheezing (32%), eye irritation (30%), coughing (26%), and reduction in lung function capacities including forced vital capacity (FVC), and forced expiratory volume in the first second (FEV₁). Smit, *et al*, found a significant dose-response relationship for lower respiratory symptoms and flu-like and systemic symptoms in wastewater treatment workers exposed to endotoxin levels higher than 50 EU/m³.⁷ Gregov, *et al*, also showed a high prevalence of headache, fatigue and nausea in wastewater treatment workers exposed to cultivable bacilli.⁸ In contrast, Khuder, *et al*, did not find any significant difference in the prevalence of respiratory symptoms between aerosol-exposed employees and unexposed subjects.⁹ Likewise, Jeggli, *et al*, failed to demonstrate any significant

increase in the prevalence of respiratory symptoms (including dyspnea, bronchitis, and asthma) and decrease in pulmonary function test (PFT) parameters attributable to bio-aerosol exposure.

Given the above controversies, the objective of this study was thus to find out if exposure to bio-aerosols under normal working conditions in wastewater treatment plants induces any changes in the prevalence of respiratory symptoms and lung functional capacities.

Materials and Methods

This study was conducted in 10 wastewater treatment plants of petrochemical industries in South of Iran. The study population consisted of all employees of wastewater treatment plants (194 male workers) as well as 99 randomly selected healthy workers from the same industry with similar socioeconomic and demographic status (sex, ethnic background, education, smoking habits) without history of exposure to other contaminants known to cause respiratory disorders. They participated voluntarily in the study. The study was conducted in accordance with the latest version of Declaration of Helsinki code of ethics.

Respiratory Symptoms and Pulmonary Function Tests (PFTs)

Respiratory symptom questionnaire, as suggested by the American Thoracic Society (ATS),¹¹ was completed for all studied workers through interview conducted by one of the authors who was fully familiar with the task. The Persian version of the questionnaire has so far been used in several studies by the same authors.¹²⁻¹⁵ Apart from the respiratory symptoms (*ie*, chronic cough, wheezing, phlegm, bronchitis, *etc*), this questionnaire contained questions regarding smoking habits, medical and family history, and jobs held before employment at wastewater treatment plant.

TAKE-HOME MESSAGE

- Wastewater treatment workers are vulnerable to a wide range of chemical pollutants and biological contaminants.
- The prevalence of respiratory symptoms among exposed persons was significantly higher than that of unexposed people.
- The workers had symptoms of fatigue, skin problems, throat irritation, productive cough, stomach problems, chronic bronchitis, wheezing, eye irritation, coughing, and reduction in lung function capacities.
- Exposure to bio-aerosols would increase the prevalence of respiratory symptoms and decrease the pulmonary function test parameters.

PFTs, including vital capacity (VC), FVC, and FEV₁, were measured with a portable calibrated spirometer (Vitalograph, Fukuda Sangyo CO, Ltd, Japan) on site. The mean percentage predicted value was based on subject's age, weight, standing height, sex, and ethnicity, as calculated and adjusted by the spirometer.

To assess the cross-shift changes in PFT parameters and to differentiate between possible acute and chronic effects of exposure to bio-aerosols, PFTs were measured at the beginning (pre-shift) of the first working day, when subjects returned to

work after being away for three consecutive days, at the end of the first working day (post-shift), and at the end of the last working day of the week.

Subjects were asked not to take shower, abstain from eating heavy food and not to smoke for at least two hours prior to the test. The standing height and weight of each subject were measured in his normal working clothes. Before conducting the test, they were asked to rest for five minutes. They were then requested to stand in front of the spirometer in a comfortable position with a nose clip put on. At least three

Table 1: Demographic characteristics and smoking habits of studied participants, and ambient air concentrations of bio-aerosols in the studied wastewater treatment plants. Values are mean (SD), median [IQR], or frequency (%).

Parameter	Unexposed workers (n=99)	Exposed workers (n=194)	p value
Age (yr)	34.7 (6.1)	35.3 (7.6)	0.403
Weight (kg)	82.1 (13.3)	80.1 (12.4)	0.197
Height (cm)	175.3 (6.7)	173.7 (13.1)	0.234
Length of service (yr)	6 [9]	7 [6]	0.041
Duration of smoking (yr)	21 [18]	7 [10]	0.002
Smoking	45 (45%)	114 (58.8%)	0.766
Light	17 (38%)	40 (35.1%)	0.361
Heavy	28 (62%)	74 (64.9%)	0.426
Workplace ambient air concentration of bio-aerosols (CFU/m ³)			
Bacteria	45 [4.7]	308 [305.6]	<0.001
Fungi	12 [6]	34.1 [24.2]	<0.001
Education			
Under diploma	14 (14%)	45 (22.7%)	0.418
Diploma	49 (49%)	82 (41.4%)	
BSc	29 (29)	65 (32.8)	
MSc	7 (7%)	6 (3.0%)	
Marital status			
Single	10 (10%)	29 (14.6%)	0.274
Married	89 (90%)	169 (85.4%)	

Table 2: Time-weighted average (TWA) of exposure to bio-aerosols among various occupational groups in the studied wastewater treatment plants (n=194).

Occupational group	n (%)	Approximate working time (hr) in...		TWA (CFU/m ³) median [IQR]	
		Site (Outdoor)	Control room (Indoor)	Bacteria*	Fungi*
Board man	8	0	75 (38.7%)	137 [11] ^a	76.5 [8.7] ^e
Site man	9	3	91 (46.9%)	199.7 [31] ^b	50 [19.7] ^{f,i}
Lab staff	8	0	8 (4.1%)	38.5 [101.5] ^c	3 [1.4] ^g
Cleaning staff	5	7	10 (5.2%)	355 [180] ^d	32 [72.7] ^{h,i}
Security officer	4	4	10 (5.2%)	346.5 [65.2] ^d	30 [78] ^{e,f,h,i}
p value (Kruskal-Wallis)				<0.001	<0.001

*Mann-Whitney U test: Groups with different superscripts are significantly different.

acceptable maneuvers were performed for each person and the highest volumes were selected for the study.

Measurement of Ambient Air Concentrations of Bio-aerosols

To assess the extent of exposure to bio-aerosols, total bacteria and fungi concentrations were measured in different units of industrial wastewater treatment plants according to the National Institute of Occupational Safety and Health (NIOSH) analytical method No. 0800.¹⁶ For this purpose, air samples were collected on blood agar and dextro-agar in Andersen single-stage sampler (SKC) with a flow

rate of 28.3 L/min for 10 min. Collected samples were immediately shipped to the lab and incubated for 48 hrs. Incubated samples were then counted to determine the concentrations of colonies adjusted by the volume of air sampled and expressed in CFU/m³. Time weighted average (TWA) of workers exposure to bio-aersols was calculated based on the concentration of bio-aerosols in each unit of wastewater plant as well as the corresponding approximate time workers spent in each unit.

Smokers were arbitrary classified into two subgroups—“light smokers,” those smoke four or less cigarettes per day, and “heavy smokers,” those smoke more than four cigarettes per day.

Statistical Analysis

SPSS® for Windows® ver 16 was used for statistical analysis. Normal distribution of parameters was evaluated by one-sample Kolmogrov-Smirnov test. Equality of variances was examined by Leven's test. *Student's t* test was used for comparison of means between two normally distributed groups, otherwise Mann-Whitney U test was used. χ^2 or Fisher's exact test, when appropriate, was used to compare categorical

Table 3: Frequency (%) of respiratory symptoms in the exposed and unexposed workers

Symptom	Unexposed (n=99)	Exposed (n=194)	OR (95% CI)
Cough	9 (9)	45 (23.2)	2.9 (1.4 to 6.3)
Phlegm	13 (13)	51 (26.3)	2.3 (1.2 to 4.5)
Productive cough	10 (10)	49 (25.3)	2.9(1.4 to 6.0)
Wheezing	8 (8)	37 (19.1)	2.7 (1.2 to 6)
Breathlessness	11 (11)	39 (20.1)	2 (1 to 4)

variables, when appropriate. Multiple linear regression was used to control for the effects of confounding variables (smoking, age, weight, height, *etc*) on the changes in PFT parameters.

Linear regression analysis was also used to assess the association between years of exposure and possible changes in PFT parameters. A p value <0.05 was considered statistically significant.

Results

Demographic characteristics and smoking habit of studied workers as well as the concentration of the bio-aerosols in the ambient air of wastewater treatment plants are shown in Table 1. Except for the length of service, duration of smoking, and the exposure level, there were no statistically significant differences between demographic characteristics of the exposed and unexposed groups.

The level of exposure of different occupational groups to bio-aerosols was significantly different among occupational groups (Table 2). Cleaning operators and security officers had the highest level of exposure to bio-aerosols.

There was no significant difference in the prevalence of cough, phlegm, productive cough, wheezing, and breathlessness between indoor (*ie*, control room, and lab staff) and outdoor (*ie*, site man, cleaning staff, and security staff) workers (Fig 1).

Pre-shift abnormal PFT, including obstructive, restrictive, and combined patterns, was observed in 30 (36%) of 83 indoor workers compared to 48 (43.3%) of outdoor workers ($p=0.375$). The post-shift frequencies were 34 (41%), and 62 (56.8%), respectively ($p=0.073$).

Changes in PFT parameters at various times are shown in Figure 2. PFT parameters of exposed and unexposed workers were different; this difference was more pronounced after exposure to bio-aero-

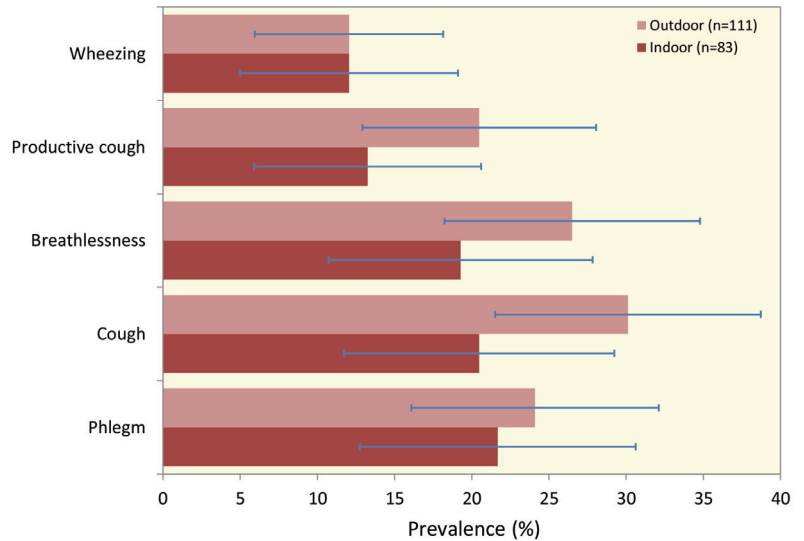


Figure 1: Prevalence of respiratory symptoms among indoor and outdoor workers of wastewater treatment plants (n=194). Error bars represent 95% CI.

sols. Most of the measured parameters were significantly ($p<0.001$) lower in the exposed compared to unexposed groups.

The exposed workers had a significantly higher prevalence of respiratory symptoms than the unexposed workers (Table 3).

Adjusting for age, weight, height, duration and severity of smoking, logistic regression analysis revealed statistically significant associations between exposure to bio-aerosols and all respiratory symptoms (Table 4).

Table 4: Association between exposure to bio-aerosols and prevalence of respiratory symptoms after adjusting for participants' age, weight, height, duration and severity of smoking using logistic regression analysis

Dependent variable	OR (95% CI)
Cough	4.2 (1.7 to 10.1)
Phlegm	2.4 (1.2 to 5.2)
Productive cough	2.9 (1.3 to 6.4)
Wheezing	5.2 (2.0 to 13.2)
Breathlessness	2.4 (1.2 to 5.2)

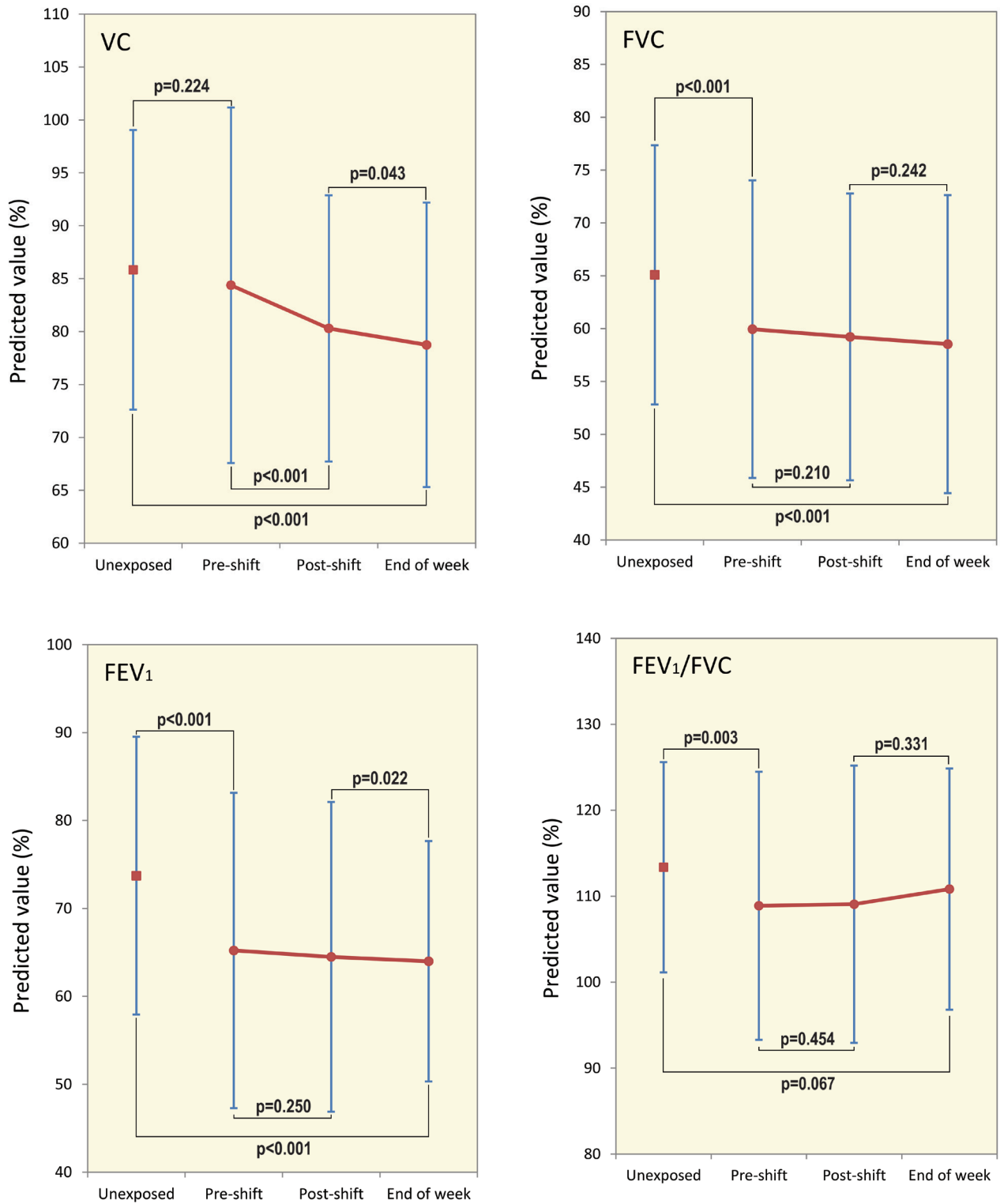


Figure 2: Variation of the measured PFT parameters at various times in exposed and unexposed workers. Error bars represent SD.

After adjusting for age, weight, height and severity of smoking, multiple linear regression analysis showed statistically significant associations between exposure to bio-aerosols and all studied PFT parameters (Table 5).

Discussion

Except for the length of service, duration of smoking and exposure concentration, exposed and unexposed workers had similar socioeconomic and demographic characteristics as they were from the same industry with almost identical age, education, marital status, weight, ethnicity and smoking habits. None of the participants had past medical or family history of chronic respiratory disease.

We found a significantly higher prevalence of respiratory symptoms in exposed compared to unexposed workers. These findings were similar to the results of previous reports.^{5,7}

After adjusting for confounders, significant associations were found between exposure to bio-aerosols and all respiratory symptoms. Other researchers also reported higher prevalence of the symptoms among wastewater treatment workers.^{3,7,17} All these explain the higher prevalence of respiratory symptoms and abnormal PFT in wastewater treatment workers who are at a significantly higher exposure to bio-aerosols, compared to unexposed workers. As the number of smokers and the severity of smoking were not significantly different between exposed and unexposed groups, the observed higher prevalence of respiratory symptoms and significant decrements in the measured PFT parameters in the exposed compared to unexposed group, were unlikely due to smoking. Results of multiple linear regression analysis further confirmed this argument.

After controlling the confounders, we found a significant increase in the preva-

Table 5: Association between exposure to bio-aerosols and changes in the PFT parameters after adjusting for participants' age, weight, height, duration and severity of smoking using multiple linear regression analysis

Dependent variable	Regression coefficient β (95% CI)
VC	-0.39 (-0.23 to -0.54)
FVC	-0.73 (-0.71 to -0.76)
FEV ₁	-0.67 (-0.64 to -0.70)
FEV ₁ /FVC	-0.67 (-0.65 to -0.68)

lence of respiratory symptoms as well as significant decrements in the PFT parameters of wastewater treatment workers compared to the comparison group. However, in a 5-year study conducted by Jeggli, *et al*,¹⁰ they did not find any significant associations between respiratory symptoms and PFTs of wastewater treatment workers. While the reasons for this discrepancy is not known, it might be attributed to the difference in the selection of the comparison group between the two studies. Their comparison group was selected from a group of gardeners, waterway maintenance, public transport, and forestry workers, which probably had more exposure compared to our comparison group workers (office staff).

We found that the level of exposure to bio-aerosols for outdoor workers (particularly, cleaning operators) were significantly higher than that for indoor workers. However, the prevalence of respiratory symptoms and the PFT parameters of the two groups were not significantly different. This finding was in line with the study of Smit, *et al*,⁷ on 97 indoor and 371 outdoor workers, and Khuder, *et al*,⁹ study on 150 participants. According to Smit, *et al*, this observation could be explained by the fact that indoor workers (board men and lab staffs) were exposed to bio-aerosols occasionally (*eg*, during sampling and site

visit). On the other hand, most of the outdoor workers spent a considerable time during their work shift indoor (*eg*, in control room) where exposure to bio-aerosol was low.

To differentiate acute (changes that are reversible following a 72-hour exposure-free period) and chronic respiratory effects (irreversible changes, which remain significantly different from the baseline values of the comparison group even after a 72-hour exposure-free period), we compared PFT parameters at various times. Exposure to bio-aerosols was associated with significant reductions in most PFT parameters in exposed workers compared to the comparison group. These changes were more prominent after exposure that demonstrated exposure to bio-aerosols during the work shift aggravated the decrements in lung functional capacities. The results of multiple linear regression analysis further confirmed this proposition.

These findings were in line with the results of Richardson, *et al*,¹⁸ who found FEV_1/FVC was significantly lower in wastewater treatment workers in comparison with a comparison group. Contrarily, Jeggli, *et al*,¹⁰ did not find any significant differences in the prevalence of respiratory symptoms and PFT parameters between exposed and unexposed groups.

PFTs indicated a mixture of partially reversible acute and irreversible chronic changes as the pre-shift measured parameters in the exposed group were significantly lower than post-shift values. Additionally, they were significantly lower than those of the comparison group.

One of the limitations of the current study was its cross-sectional nature that hampers our ability to find any cause-and-effect relationships. However, several lines of circumstantial evidence indicate that increased prevalence of respiratory symptoms as well as decrements in lung functional capacities are very likely to be the

consequence of exposure to bio-aerosols. The exposed subjects did not have any history of respiratory illnesses at the time of their employment in the plants. Multiple linear and logistic regression analyses showed that after adjusting for confounders, significant associations existed between exposure to bio-aerosols and the prevalence of respiratory symptoms and decreased PFTs values. PFT parameters of exposed group were generally better after the exposure ceased. However, despite this partial recovery, the difference between most PFT parameters in the exposed and unexposed groups remained significant.

The spirometric pattern observed in this study has provided evidence in favor of an obstructive ventilatory disorders, because the hallmark of this condition is a reduced expiratory flow rate (usually measured by FEV_1) and a significant reduction in FEV_1/FVC ratio.¹⁵ This finding was in accord to the potential of bio-aerosol to produce bronchial and respiratory tract hyper-responsiveness and allergic reactions mentioned earlier.^{12,19,20}

Acknowledgements

The authors wish to sincerely thank Dr. J Hassanzadeh, clinical epidemiologist, Department of Epidemiology, School of Health, Shiraz University of Medical Sciences, for his invaluable and skillful assistance in data analysis.

Conflicts of Interest: None declared.

Financial Support

This study was funded by National Iranian Petrochemical Company (contact no. 105928). It is registered in the office of Vice Chancellor for Research Affairs, Shiraz University of Medical Sciences (No. 91-6013).

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