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Respiratory symptoms and pulmonary functions before and after pesticide application in cotton farming

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Abstract

Ojective. To investigate respiratory health problems related to pesticide exposure in the inhabitants of agricultural areas.
Materials and method. This study included 252 participants prior to pesticide application and 66 participants from the first group after pesticide application across four cotton farms. Symptom questionnaires were filled out by participants and respiratory function tests were measured before and after pesticide exposure. In addition, PM_{10}, $PM_{2.5}$, air temperature, and humidity were measured in all four farming villages before and after pesticide administration.
Results. PM_{10} and $PM_{2.5}$ levels were significantly increased after pesticide application. After pesticide application, all participants' nose, throat, eye, and respiratory complaints increased significantly. Expected forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) percentage values decreased significantly. The rates of FVC and FEV_1 values lower than 80% were 23.5% and 22%, respectively, before pesticide application, and this rate increased to 42.4% and 43.1%, respectively, after pesticide application. There was a significant negative correlation between PM_{10} levels and FVC, FEV_1, and PEF values. After $PM_{2.5}$ pesticide application, the risk of experiencing burning in the mouth, nose, and throat increased by 2.3-fold (OR: 2.316), 2.6-fold for burning symptoms in the eyes (OR: 2.593), 2.1-fold for wheezing (OR: 2.153), and 2.2-fold for chest tightness (OR: 2.211). With increased PM_{10} levels, the risk of chest tightness increased 1.1-fold (OR: 1.123).
Conclusions. After pesticide administration, the respiratory health of the participants deteriorated. Performing pesticide applications in agriculture with harmless methods is the most important measure to be taken to protect public health

Key words

pesticides, PM_{10}, $PM_{2.5}$, pulmonary functions, respiratory symptoms

INTRODUCTION

It is known that the pollution of particulate matter (PM) in cities and regions of concentrated industry is increasing. Particulate matter is a mixture of solid, liquid, organic, and inorganic substances. PM can remain in the atmosphere for 3–10 days, depending on environmental conditions. Under certain meteorological conditions, PM can also be transported thousands of kilometers away. Investigations have shown that agricultural activities also lead to considerable PM pollution [1]. PM-producing agricultural activities include soil cultivation, preparation for dibbling, sowing, application of fertilizers and pesticides, crop harvesting, and post-harvesting processes. Land preparation and harvesting activities in California can produce different levels of PM_{10}, and the levels of PM_{10} can be decreased [2]. Agricultural activities in the European Union countries are responsible for 5% of all $PM_{2.5}$ production and 25% of PM_{10} production [3]. In a study conducted by Bogman et al. [4], agricultural activities accounted for 24% of all PM_{10} production.

Pesticide application increases the density of PM substances in agricultural processes, and chemically active particles are transported to areas far from the application area by wind, and through inhalation also affect people living around the application area [5, 6, 7]. Pesticides are bioactive compounds used to eliminate pests and to protect crops from them. When pesticides are used intensively, they are found not only in soil, water, and crops, but also in the atmosphere. Particularly semi-volatile pesticides are commonly found in both gas and particulate form in the atmosphere [8].

The effects of pesticides on the respiratory system were explored in detail in a community working in a plant that mixes organophosphates and carbamates with alkalis. Acute findings in the employees included dyspnea, eye irritation, dryness in the nose, and occasional nasal discharge. Chronic cough, dyspnea, and nasal discharge are even more frequent findings in employees chronically exposed to pesticides. The FVC, FEF_{25}, and FEF_{50} values of the employees were found to be lower than the expected values [9].

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While discussing the adverse health effects of PM_{10} and $PM_{2.5}$ production associated with pesticide use in agricultural areas, it is advisable to assess both the health effects associated with particulate matter and the pesticide-related impact. This study aimed to investigate the effect of pesticide application on particulate matter exchange in cotton agriculture and the level of influence of such application on symptoms and pulmonary function tests.

MATERIALS AND METHOD

Subjects. The study was conducted between June – August of 2016 in the Harran province of Urfa City, a cotton-producing city located in the southeastern part of Turkey. The cotton planting period in the region is from 20 April – 15 May. The first watering in cotton cultivation takes place 40–45 days after planting, and the last watering takes place in the last week of August or the first week of September at the latest. According to this schedule, the cotton is irrigated 11 times in total, three times in June at 10-day intervals and four times in July and August at eight-day intervals. Irrigation is performed nine times at 10-day intervals during seasons in which water is scarce. The pesticide included a mixture of Lambda-Cyhalothrin (7 g/da), Emamectin benzoate (4 g/da) and Nitrogen (40 g/da), phosphorus pentaoxide (200 g/da), and zinc (120 g/da) is applied to kill green worms (*Helicover paarmigera*), which are harmful to cotton plants. Pesticide application for green worms is usually carried out at the end of June, from July 15–25, and during mid-August. A total of 252 volunteers living in four farming villages (Giyimli, Küçük Minareli, Büyük Minareli, and Bozyaka) spread over 65 km2 were evaluated before the application of pesticides (mid-June). After pesticide application (mid-August), 66 people from the first group agreed to participate in a reevaluation of their health. Ethical approval for this study was given by the Ethics Committee of Harran University.

Symptoms. Individuals were asked about the presence of symptoms, such as nose and throat burning or stinging; eyes burning, stinging, or watering; coughing; phlegm; wheezing; and a feeling of chest tightness before and after pesticide application. Symptom data was collected with a standard questionnaire.

Spirometry. Individuals were subjected to respiratory function tests (MIR SpiroLab 3 Spirometer) in indoor settings (village rooms, schools, and headman rooms) before and after pesticide application. Spirometric measurements were performed by four people in a sitting position (ZS, SH, PA, BO). At least three times, technically acceptable, forced vital capacity maneuvers were performed, and the highest spirogram was recorded. Spirometric values were expressed as a percentage of the expected value. The forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/ FVC and maximum mid-expiratory flow rate (MMFR) were assessed before and after the application of the pesticide.

Dust measurement. PM_{10} is defined as particles with a diameter of 10 μm or less, and $PM_{2.5}$ is defined as those with a diameter of 2.5 μm or less. A calibrated pDR 1500 (Thermo Scientific Personal Data RAM pDR) device and two calibrated cyclones were used to make PM_{10} and $PM_{2.5}$ measurements in the environment. Device calibration was performed before each sampling. Before starting sampling, the coordinates and altitude of the working area were determined by a Magellan GPS device. Fifteen-minute measurements of PM_{10} and $PM_{2.5}$ were made with the cyclones. Measurements were made at the four village centers (in four villages spread over 65 km2) before agricultural spraying (in mid-June) and within 15 minutes and 48 hours after agricultural spraying (in mid-August).

Statistical data. Analyzed using the Statistical Package for Social Sciences (SPSS) software version 21.0 (SPSS Inc., Chicago, IL).An independent-samples t-test was used to compare independent groups, whereas a paired samples t-test was used to compare dependent groups. A repeated ANOVA test was used for multiple comparisons. The distribution of categorical variables in both groups was compared using Pearson's chi-square test. Data are expressed as the mean ± standard deviation (SD). Categorical variables are expressed as frequencies and percentages. Statistical significance was assumed at $p<0.05$. A Wilcoxon test was used to compare mean PM_{10}, $PM_{2.5}$, heat, and humidity levels obtained before and after pesticide applications. A McNemar test was used to compare paired proportions before and after pesticide applications. Linear regression was used to investigate the relationships among participant respiratory functions, gender, smoking history, and levels of PM_{10} and $PM_{2.5}$. Odds ratios were calculated using a logistic regression analysis for each respiratory and eye, nose, and throat symptom (age, gender, smoking status and levels of $PM_{2.5}$ and PM_{10} after pesticide application were the predictors).

RESULTS

The study included 252 subjects (108 males [42.9%] and 144 females [57.1%]) before pesticide application and 66 (30 males [54.5%] and 36 females [45.5%]) after pesticide application, with an average age of 42.3 and 42.3 before and after pesticide application, respectively. Characteristics of the individuals participating in the study are shown in Table 1.

The mean duration of exposure of individuals to pesticides was 15.2 ± 2.7 (range: 1–53) years.

The frequency of symptoms that occurred during the previous pesticide-spraying period is given in Table 2. Among the five most frequently observed symptoms due to pesticide application were eye burning, dyspnea, headache, cough, and itching. PM_{10}, $PM_{2.5}$, and average values of temperature and humidity measured in the village before and after pesticide application—are shown in Table 3. The frequency of symptoms affecting the mouth, nose, throat, eyes, and respiratory system before and after spraying and pulmonary function tests before and after pesticide application are provided in Table 4.

After pesticide application, all nose, throat, eye, and respiratory symptoms increased significantly and expected FVC and FEV_1 percentage values decreased significantly. The rates of FVC and FEV_1 values lower than 80% were 23.5% and 22%, respectively, before pesticide application, and these rates increased to 42.4% and 43.1%, respectively, after pesticide application.

The proportion of those with FEV_1 / FVC below 70% fell from 5.3% to 1.5%. The percentage of MMFRs expected to be less than 65% percent increased from 29.1% to 37.1%.

Table 1. Characteristics of study subjects

	Before pesticide n=252	Before pesticide %	After pesticide n=66	After pesticide %
Gender				
Male	108	42.9	30	54.5
Female	144	57.1	36	45.5
Smoking				
Yes	123	48.8	31	47.0
No	129	51.2	35	53.0
Villages				
Giyimli	91	36.1	13	19.7
Küçük Minareli	77	30.6	14	21.2
Büyük Minareli	57	22.6	29	43.9
Bozyaka	27	10.7	10	15.2
Graduate	n=252	%	n=63	%
Illiterate	98	38.9	27	42.9
Primary school	90	36.1	18	28.6
Higher education	64	25.0	18	28.5
Previous diseases				
None	143	56.7	41	62.1
Cardiovascular	25	9.9	7	10.6
COPD	14	5.6	5	7.6
Asthma	11	4.4	2	3.0
Other	59	23.4	11	16.7

Table 2. Symptoms of individuals during previous pesticide spraying periods

	No. of subjects	Percent (%)
Eye burning	114	45.2
Dyspnea	95	37.7
Headache	79	31.3
Cough	77	30.6
Itching	68	27.0
Weakness	62	24.6
Fatigue	55	21.8
Nausea	46	18.3
Blurred vision	42	16.7
Inappetency	36	14.3
Drowsiness	33	13.1
Muscle-joint pain	32	12.7

Table 3. Mean values of PM_{10}, $PM_{2.5}$, temperature and humidity in the villages before and after pesticide application

	Mean		P
	Before pesticide	After pesticide	
PM_{10}			
Giyimli	11.7	334.8	<0.001
Küçük Minareli	20.2	328.2	0.001
Büyük Minareli	27.8	313.5	<0.001
Bozyaka	23.8	319.3	<0.001
$PM_{2.5}$			
Giyimli	4.7	13.2	<0.001
Küçük Minareli	5.2	11.4	0.001
Büyük Minareli	8.2	15.0	<0.001
Bozyaka	12.2	17.2	<0.001
Heat			
Giyimli	32.1	37.8	<0.001
Küçük Minareli	31.8	36.7	<0.001
Büyük Minareli	31.6	36.1	<0.001
Bozyaka	31.7	36.8	<0.001
Humidity			
Giyimli	25.5	52.8	<0.001
Küçük Minareli	25.5	52.8	0.001
Büyük Minareli	28.2	52.8	<0.001
Bozyaka	34.6	56.3	0.002

Table 4. Pre-and post-spraying symptoms and pulmonary functions of the study group

	Before pesticide n=252		After pesticide n=66		P
	n	%	n	%	
Mouth-nose-throat burning	24	9.5	47	71.2	<0.001
Sneezing	6	2.4	44	66.7	<0.001
Eye burning	30	11.9	51	77.3	<0.001
Cough	13	5.2	45	68.2	<0.001
Phlegm	10	4.0	43	65.2	<0.001
Wheezing	11	4.4	41	62.1	<0.001
Dyspnea	22	8.7	44	66.7	<0.001
Chest tightness	17	6.7	41	62.1	<0.001
	Before pesticide n=247 (Mean, SD)		After pesticide n=66 (Mean, SD)		P
FVC % predicted	92.3 ± 22.6		83.7 ± 24.3		<0.001
FEV_1 % predicted	91.0 ± 25.8		84.4 ± 23.4		<0.001
FEV_1/FVC	82.8 ± 10.0		82.5 ± 6.6		0.168
MMFR % predicted	78.8 ± 28.5		78.0 ± 30.8		0.284
PEFR % predicted	68.7 ± 28.5		65.9 ± 26.5		0.185
	Before pesticide		After pesticide		P
	n	%	n	%	
FVC<80% predicted	58	23.5	28	42.4	<0.001
FEV_1<80% predicted	54	22.0	28	43.1	<0.001
FEV_1/FVC<70%	13	5.3	1	1.5	0.045
FEV_1/FVC<75%	27	10.9	1	1.5	>0.05
MMFR<65%	71	29.1	23	37.1	0.001

Table 5. Pre and post pesticide frequencies of health complaints and mean values of pulmonary functions of 66 subjects

	Before pesticide n=66		After pesticide n=66		p
	n	%	n	%	
Mouth-nose-throat burning	6	9.1	47	71.2	<0.001
Sneezing	2	3.0	44	66.7	<0.001
Eye burning	4	6.1	51	77.3	<0.001
Cough	2	3.0	45	68.2	<0.001
Phlegm	0	0.0	43	65.2	<0.001
Wheezing	2	3.0	41	62.1	<0.001
Dyspnea	6	9.1	44	66.7	<0.001
Chest tightness	3	4.5	41	62.1	<0.001
	Before pesticide n=66 (Mean, SD)		After pesticide n=66 (Mean, SD)		p
FVC % predicted	92.3 ± 22.6		83.7 ± 24.3		<0.001
FEV_1 % predicted	92.7 ± 24.9		84.5 ± 23.5		<0.001
FEV_1/FVC	82.8 ± 10.0		82.5 ± 6.6		0.768
MMFR % predicted	78.8 ± 28.5		78.0 ± 30.8		0.786
PEFR % predicted	68.7 ± 28.5		65.9 ± 26.5		0.185
	Before pesticide		After pesticide		p
	n	%	n	%	
FVC<80% predicted	14	21.2	26	39.4	0.003
FEV_1<80% predicted	15	22.7	28	42.4	0.002
FEV_1/FVC<70%	3	4.5	1	1.5	0.157
FEV_1/FVC<75%	7	10.8	1	1.5	0.014
MMFR<65%	17	26.6	23	35.9	0.109

Table 6. Analysis of correlation between respiratory functions and age, smoking, PM_{10}, $PM_{2.5}$ levels and distance to the field of pesticide application

	FVC	FEV1	FEV1/FVC	PEF	MMFR
Age					
R	-.425	-.441	-.337	-.361	-.466
P	<0.001	<0.001	0.006	0.003	<0.001
Smoking duration					
R	-.433	-.472	-.243	-.254	-.518
P	0.008	0.004	0.154	0.141	0.001
PM_{10}					
R	-.586	-.473	.154	-.413	-.214
P	<0.001	<0.001	0.225	0.001	0.089
$PM_{2.5}$					
R	.322	.224	-.156	.135	-.039
P	0.009	0.075	0.219	0.287	0.758
Distance to pesticide area					
R	.081	.048	.034	-.085	-.016
P	0.534	0.709	0.790	0.514	0.903

Table 7. Effects of age, gender, smoking, PM_{10}, $PM_{2.5}$ values on pulmonary function (Linear regression analysis)

	Unstandardized coefficient B	**T**	**P**
Age			
FVC	-.562	-3.785	<0.001
FEV1	-.590	-3.808	<0.001
FEV1/FVC	-.138	-2.607	0.012
PEF	-.551	-3.215	0.002
MMFR	-.850	-3.929	<0.001
Gender			
FVC	-1.368	-.304	0.762
FEV1	3.053	.650	0.518
FEV1/FVC	-.586	-.364	0.717
PEF	19.694	3.830	<0.001
MMFR	15.778	2.446	0.017
Smoking			
FVC	4.173	1.165	0.249
FEV1	3.346	0.896	0.374
FEV1/FVC	1.781	1.392	0.169
PEF	3.101	.730	0.468
MMFR	5.775	1.093	0.279
PM_{10}			
FVC	-2.108	-5.230	<0.001
FEV1	-1.666	-3.963	<0.001
FEV1/FVC	.129	.896	0.374
PEF	-1.605	-3.502	0.001
MMFR	-1.375	-2.401	0.020
$PM_{2.5}$			
FVC	-4.464	-1.843	0.070
FEV1	-4.090	-1.619	0.111
FEV1/FVC	.023	.027	0.979
PEF	-4.577	-1.644	0.105
MMFR	-7.197	-2.037	0.046

Table 8. Odds ratio values of $PM_{2.5}$ and PM_{10} for symptoms

	Exp (B)	P	95% C.I. Exp (B)	
			Lower	Upper
Mouth-nose-throat burning				
$PM_{2.5}$	2.316	0.011	1.213	4.419
Eye burning				
$PM_{2.5}$	2.593	0.014	1.212	5.547
Wheezing				
$PM_{2.5}$	2.153	0.015	1.164	3.981
Chest tightness				
$PM_{2.5}$	2.211	0.012	1.190	4.108
PM_{10}	1.123	0.047	1.002	1.259

* Logistic regression analysis step 1 measures included age, gender, smoking, post-pesticide $PM_{2.5}$ and PM_{10} variables.

Health complaints of 66 subjects underwent both before and after evaluation increased and expected FVC and FEV_1 values decreased significantly. The rates of FVC and FEV_1 values lower than 80% were 21.2% and 22.7%, respectively, before the pesticide period, and these rates increased to 39.4% and 42.4%, respectively after pesticide period (Tab. 5).

The relationships between pulmonary function parameters and PM_{10} and $PM_{2.5}$ levels, age, duration of smoking, except pesticide area distance from the treated place after pesticide administration, were statistically significant. There was a significant negative correlation between PM_{10} levels and FVC, FEV_1, and PEF values, whereas there was a significant positive correlation between $PM_{2.5}$ levels and FVC. A significant negative correlation was also observed between age and percent predicted FVC, FEV_1, FEV_1/FVC, PEF, and MMFR values, as well as between duration of smoking history and FVC, FEV_1, and MMFR values (Tab. 6).

The presence was analyzed (by linear regression analysis) of independent effects of age, gender, cigarette use, and PM_{10} and $PM_{2.5}$ levels over expected percentage FVC, FEV_1, FEV_1/FVC, PEF, and MMFR values. When linear regression analysis was applied, age had significant negative and independent effects over all respiratory function values. Gender had an independent effect on PEF and MMFR (PEF and MMFR values were higher in males). There was a significant, independent, and negative effect of the PM_{10} variable overall values of the respiratory function, except for the FEV_1/FVC ratio. The $PM_{2.5}$ variant had significant, independent, and negative effects on MMFR values (Tab. 7).

Table 8 shows the respiratory symptoms observed after pesticide administration and the odds ratio for respiratory function tests (logistic regression analysis). With increased $PM_{2.5}$ levels, the risk for burning in the mouth, nose, and throat increased 2.3-fold, and the risk increased 2.6-fold for burning symptoms in the eyes, 2.1-fold for wheezing, and 2.2-fold for chest tightness. With increased PM_{10} levels, chest tightness increased 1.1-fold.

DISCUSSION

In this study, a significant increase in both PM_{10} and $PM_{2.5}$ levels was observed after emomectin benzoate and cyhalothrin application. The increase in PM_{10} levels exceeded the value of the World Health Organization's (WHO) 24-hour exposure limit of 50 μg/m^3 by six-fold. The increase in $PM_{2.5}$ levels was found to be below 25 μg/m^3, which is the 24-hour exposure limit. The most commonly observed symptoms after pesticide application were burning in the eyes, shortness of breath, headache, cough, and itching. After pesticide application, all nose, throat, eye, and respiratory symptoms increased significantly in participants. In addition, the expected FVC and FEV_1 percentage values decrease significantly.

There was a significant correlation between PM_{10} levels and FVC, FEV_1, and PEF values, whereas there was a significant positive correlation between $PM_{2.5}$ levels and FVC values. Although increased $PM_{2.5}$ levels were correlated with a 2.3-fold increase in risk of burning in the mouth, nose and throat; a 2.6-fold increase in risk of burning symptoms in the eyes; a 2.1-fold increase in risk of wheezing; and a 2.2-fold increase in risk of chest tightness, the increase of PM_{10} levels were correlated only with a 1.1-fold increase in risk of chest tightness.

A significant increase in upper respiratory tract symptoms, including coughing, phlegm, shortness of breath, chest tightness and wheezing, was observed in adults due to increased PM_{10} and $PM_{2.5}$ pollution after pesticide application [10]. The data on increased cough and phlegm due to pesticide application are increasing [11, 12]. In a study conducted by Hoppin et al., 654 farmers with a history of pesticide exposure were found to have doctor-diagnosed chronic bronchitis. In this study, which identified 11 pesticides shown to increase the risk of chronic bronchitis, OR was observed as 1.5 with Heptachlor use. The risk of chronic bronchitis increased in the presence of predominantly high pesticide exposure, and in those with additional pesticide exposure due to non-farming related activities [13].

In another study conducted with men and women, chronic bronchitis risk was found to be increased with the use of dichlorvos (OR=1.63), dichlorodiphenyltrichloroethane (DDT) (OR=1.67), cyanazine (OR=1.88), paraquat (OR=1.91), and methyl bromide (OR=1.82) [14]. In the same study, the use of pesticides for 120 days or more during a participant's lifetime increased the risk of chronic bronchitis. Wheezing has been observed in people who use commercial preparations of dichlorvosasan insecticide [15], and reports of pulmonary fibrosis and wheezing due to paraquat herbicide have also been made [16, 17]. Employees in grain storage have reported wheezing and shortness of breath with methyl bromide acute exposure [18]. In the presented study, it was found that participants who had been exposed to pesticides due to living within one of four villages within 65km^2 of the application area, experienced burning of the mouth, nose, and throat (71.2% of participants), sneezing (66.7% of participants), burning (77.3% of participants), coughing (68.2% of participants), phlegm (65.2% of participants), wheezing (62.1% of participants), dyspnea (66.7% of participants), and a feeling of tightness in the chest (62.1% of participants).

With the increase of $PM_{2.5}$ levels, after the administration of emomectin benzoate and cyhalothrin, the risk of burning in the mouth, nose, and throat, increased by 2.3-fold, the risk of burning in the eyes increased by 2.6-fold, the risk of wheezing increased by 2.1-fold, and the risk of chest tightness increased by 2.2-fold. However, increased PM_{10} levels were only correlated with a 1.1-fold increase in the risk of chest tightness.

Lopez et al. detected 40 different pesticides in the pesticide-treated agricultural areas in which they measured pesticides in the atmospheric PM_{10}, indicating that 37% of them were insecticides. The same authors found Abamectin, an emomectin benzoate analog, in the context of atmospheric PM_{10}. Both insecticides are macrolide compounds, which are in the organic dust group [19]. In the presented study, PM_{10} measurements exceeded the value of the World Health Organization's (WHO) 24-hour exposure limit of 50 μg/m^3 by six-fold (http://www.who.int/mediacentre/factsheets/fs313/en/). Based on the literature, it can be argued that these particles contain emomectin benzoate and cyhalothrin. Short- and long-term exposures to PM_{10} and $PM_{2.5}$ have been associated in numerous studies with asthma exacerbations, respiratory symptoms, and hospital admissions [10]. The presented study demonstrates an association between emomectin benzoate, cyhalothrin, and associated particulate contamination and a 62–77% increase in upper respiratory, lower respiratory, and eye symptoms. Although $PM_{2.5}$ levels were below the WHO 24-hour exposure limit of 25 μg/m^3, there was an increase in the atmosphere compared to the previous measurements, and there were finer particles. The long-term effects of PM were not assessed in the current study.

Studies investigating the effects of pesticides on pulmonary function tests have produced different results. There are publications showing that FVC, FEV_1, and FEV_1/FVC values are decreased due to the use of organophosphate insecticide [20, 21, 22]. In farmers using an organophosphate spray, it was observed that the reduction in respiratory functions was compatible with a restrictive pattern and accompanied by a decrease in acetylcholinesterase levels in the blood. Employees involved in the production of carbamate and pyrethroid pesticides were also found to have significantly lower FEV_1/FVC ratios and MMFR values in comparison to controls. However, significant decreases in respiratory function after employee exposure to pesticides were not reported. In a study conducted by Alif et al., pesticide and herbicide exposure increased fixed airway obstruction risk by 1.74- and 2.04-fold, respectively [23]. In the presented study, the rate of FVC and FEV_1 under 80% of predicted values before pesticide exposure was higher compared to those after the pesticide use. The study group in this study had an average of 15 years of exposure to pesticides. The authors were not able to perform a reversibility test. The pre-pesticide FEV_1/FVC ratio less than 70% was 5.3%, and the post-pesticide level was 10.9%. Although there was no control group in the presented study, it can be argued that long-term pesticide exposure may lead to both obstructive and restrictive dysfunctions. The rate of post-pesticide FVC and FEV_1 individuals falling below 80% was above 40%, whereas the FEV_1/FVC ratio was below 75% in only one participant. This result showed that more restrictive respiratory dysfunction was observed with the combination of cyhalothrin and emomectin benzoate.

In the current study, one of the active pesticides, cyhalothrin, is an insecticide of the pyrethroid group, which causes tingling and burning of the face in humans, and the findings were observed for about five hours after exposure and lasting for days. This causes irritation of the nose and throat, dizziness, headache, nausea, loss of appetite, and fatigue. According to the classification of the World Health Organization's agrochemicals, cyhalothrinis in the medium dangerous agrochemical group (Group II) [24]. In a study in which lambda-cyhalothrin was used as an insecticide, coughing or sneezing and nose or throat irritation was observed in those staying at home [25].

This is the first study to compare respiratory function and general symptoms before and after open-air application of emomectin benzoate and cyhalothrin combination. Atomic PM_{10} and $PM_{2.5}$ levels associated with emomectin benzoate (7gr/da) and cyhalothrin (4gr/da), which are used as pesticides in cotton cultivation, were shown to be increased. However, the measurement of pesticides in the particulate matter was not possible. Approximately 25% of the population in which pre-pesticide respiratory function was measured was also available for measurement after pesticide exposure. Despite this limitation, a significant decrease in the respiratory functions of the community, as well as other symptoms, were observed with the application of insecticides at the indicated doses under the given atmospheric temperature and humidity conditions. In future studies, it is important to monitor the pesticides used in open fields in cotton farming and to observe whether they are applied safely.

CONCLUSIONS

Because this study demonstrates the damage to respiratory health caused by pesticide use in agriculture, it should be expected that the use of pesticides may lead to the exploration of alternatives that would not be harmful to humans, other forms of life, and environmental health. The use of non-toxic pesticides and agricultural processes that lead to less particulate matter production during pesticide applications should be discussed, and measures to temporarily remove residents from the area during applications should be explored.

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