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BRONCHOPULMONARY PATHOLOGY IN WORKERS EXPOSED TO ORGANIC FODDER DUST

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Abstract: The purpose of this study was to investigate work-related respiratory symptoms, the prevalence of chronic lung diseases and ODTS, and to study the lung function and bronchial hyperresponsiveness in the workers of Ukrainian fodder production facilities. 240 workers of two Ukrainian fodder production plants have been examined. Dust concentrations in the air of working zone were different, reaching 48.2 mg/m^3 in the first plant and 16.8 mg/m^3 in the second. Endotoxin levels were 240.0 ng/m^3 and 1.8 ng/m^3 respectively. The length of service at the first plant exceeded 2 times that at the second. In the actual research the investigation of respiratory symptoms, lung function and bronchial reactivity was carried out. A comparison between animal feed workers and internal controls revealed work-related symptoms. The predominant symptomatic and lung function effects indicate a clinical picture related to chronic bronchitis. The prevalence of chronic bronchitis was $26.4 \pm 4.0\%$ at the first plant and $8.8 \pm 4.8\%$ at the second one ($p < 0.01$). The prevalence of respiratory troubles was related to dust exposure more strongly that to smoking. $39.7 \pm 4.4\%$ of exposed workers at the first plant and $14.7 \pm 6.0\%$ at the second one revealed organic dust toxic syndrome (ODTS). In $47.9 \pm 7.2\%$ of workers with ODTS, this syndrome was associated with chronic bronchitis. Examination of lung function revealed obstructive changes which were more expressed in exposed workers of the first plant. Lung function clearly decreased with increasing duration of employment. Obstruction of small bronchi and bronchial hyperresponsiveness (registered in 74.7% of workers) were the early signs of respiratory troubles in exposed workers.

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Key words: fodder production, organic dust, endotoxin, occupational exposure, respiratory symptoms, lung function, hyperresponsiveness, chronic bronchitis, organic dust toxic syndrome.

INTRODUCTION

Occupational exposure to dust of biological origin is increasingly related to respiratory disorders during recent years. A wide range of biological dust has been related to the risk for development of respiratory symptoms, lung function changes, allergic disorders and organic dust toxic syndrome (ODTS). The adverse effects may be associated with coffee [12], tea [34], hemp [33], tobacco [11], enzymes [13], agricultural production farms [14, 17], bioaerosols generated by new biotechnologies [14].

Epidemiological studies have demonstrated that workers exposed to organic dust have an excess of respiratory symptoms [21] changes of lung function [4] and bronchial hyperresponsiveness [26]. The most typical respiratory diseases caused by organic dust are: extrinsic allergic alveolitis, chronic bronchitis, asthma and acute reaction - ODTS [17, 19, 26, 27, 29].

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In the Ukrainian animal feed industry approximately 50,000 workers are exposed to organic dust at 500 fodder factories. The dust in animal feed factories is a heterogeneous mixture of raw material itself and other components such as fungi, bacteria and their toxins, insects and particles of animal excreta, agricultural chemicals, and inorganic matter such as silica dust [2, 23, 25, 31]. Organic dusts are often contaminated with Gram-negative bacteria and their endotoxin [10]. Endotoxin consists of lipopolysaccharide that makes up a major part of the cell wall of Gram-negative bacteria. It can be released into the environment after lysis of the bacterial cells and induces profound inflammatory effects in the lung at relatively low concentrations [1, 15].

The purpose of this study was to investigate work-related respiratory symptoms, the prevalence of chronic lung diseases and ODTS, and to study the lung function and bronchial hyperresponsiveness in the workers of Ukrainian fodder production facilities.

MATERIALS AND METHODS

Work conditions of two Ukrainian fodder production plants were examined, including dust and endotoxin concentrations. The two plants were similar in the production technology, but the second plant was more modern concerning the equipment. These facilities were considered typical for the Ukrainian animal feed industry. The total population at both plants was about 400 workes. Workers were specialized in certain tasks and worked in certain locations. All examined workers employed in different locations, were grouped into categories by job title (Tab. 2). Exposure of workers takes place mainly during unloading of raw materials and final product.

The concentrations of total dust were determined by gravimetric method with the use of APA-VP-10 filters. In both facilities personal dust sampling was performed in the workers' breathing zone during full-shift periods.

Endotoxin samples were collected on sterile glass fiber filters (Macherey-nagel). Samples were analyzed for endotoxin using the chromogenic modification of the Limulus Amebocyte Lysate test (LAL; Coatest Endotoxin Test Kit, Kabi Vitrum Diagnostica, Sweden).

A cross-sectional epidemiological study of respiratory symptoms, hypersensitivity, lung function changes and bronchopulmonary pathology prevalence was carried out. Forced expiratory lung function measurements were conducted. Measurements and procedures including BTPS (body temperature pressure saturated) adjustments and procedures of data selection were in accordance with the standards of the European Community for Coal and Steel [20]. Lung function measurements were performed during the workshift in summer. The best of two well-performed tests was used for analysis. Following variables were recorded: VC, FVC, $FEV_{1,}$ PEF, MEF_{50}, MEF_{25}, $MEF_{25/75}$, MMEF.

The methacholine challenge test was conducted using a modification of the method described by Cockcroft *et al.* [5].

RESULTS

Demographics. 240 workers (141 men and 99 women) from 2 different fodder production plants in Ukraine had been examined. The arithmetic mean age was 42.6 years, range 21–59 years. The mean length of service was 10.7 years at the first plant and 4.6 at the second one (Tab. 1).

44.1% of workers at the first plant and 28.9% at the second one were smokers (exclusively men). All workers were interviewed according to the SBMRC (Second British Medical Research Council, 1965) questionnaire. The survey was extended with questions on symptoms of ODTS. Workers were divided into 2 groups: production workers (n = 155) and non-production workers (control group, n = 85).

Exposure. 80 measurements of total dust and 11 measurements of endotoxin were performed in two facilities (Tab. 2).

Table 1. Demographics of the study population.

Gender	Age (years)				Total	Length of service (years)		
	20–30	30–40	40–50	> 50		< 5	5–10	> 10
				First facility				
Male	10	25	25	15	75	20	19	36
Female	9	18	35	11	73	15	16	42
Total number	19	43	60	26	148	35	35	78
%	12.8	29.1	40.5	17.6	100	23.6	23.6	52.8
				Second facility				
Male	19	28	15	4	66	31	35	0
Female	5	10	10	1	26	10	16	0
Total number	24	38	25	5	92	41	51	0
%	26.1	41.3	27.2	5.4	100	44.6	55.4	0

Table 2. Dust and endotoxin concentrations by job category.

Job category	Dust concentration (personal samples)				Endotoxin concentration	
	N	AM (mg/m$^{3)}$	SD	Range	N	ng/m^3
First facility						
Silo's department						
Unloaders	9	48.2	4.1	12.8-114.6	1	240.0
Crane drivers	3	8.5	0.7	5.0-14.4	–	–
Facility operators	12	23.3	1.8	7.5-62.2	1	9.0
Press operators	3	17.4	2.0	2.0-30.7	1	0.031
Production managers	6	16.4	1.6	4.2-60.6	1	5.8
Premix department						
Facility operators	6	14.2	1.9	2.4-28.7	1	0.8
Expedition workers	7	12.7	0.9	1.2-24.4	1	0.65
Sackers	3	2.3	0.4	0.8-6.0	–	–
Controls	2	1.2	0.3	0.8-1.6	1	0.008
Second facility						
Silo's department						
Unloaders	8	12.3	1.4	3.9-40.2	1	0.11
Crane drivers	4	7.9	0.8	3.9-14.7	–	–
Facility operators	6	16.8	2.0	5.6-48.2	1	1.8
Press operators	6	8.1	1.7	2.9-18.0	1	0.04
Production managers	3	10.8	1.9	5.4-21.1	–	–
Controls	2	1.6	0.1	0.4-2.8	1	0.01

N - number of measurements; AM - arithmetic mean; SD - standard deviation; – Not done.

Arithmetic means of dust exposures were used in the analysis because they are directly related to dose [21]. Personal means of total dust exposures ranged from 0.8 mg/m^3 to 114.6 mg/m^3. Mean exposures for 8 job categories ranged from 2.3 mg/m^3 (sackers) to 48.2 mg/m^3 (unloaders). Personal endotoxin exposures for job categories ranged from 0.031 ng/m^3 (press operators) to 240.0 ng/m^3 (unloaders).

Prevalence of respiratory symptoms. The prevalence of respiratory symptoms ranged from 14.8% (chest tightness) to 42.1% (wheezing) at the first plant and from 11.8% (chest tightness) to 22.4% (cough with phlegm) at the second one. Significant differences were found in the prevalence of cough at least 3 months during the last 2 years, and cough with phlegm and wheezing between workers of exposed groups of two plants (Tab. 3). The significant differences in the prevalence of above mentioned symptoms between exposed and control groups were found only at the first plant.

Organic dust toxic syndrome. 39.7 ± 4.4% of exposed workers at the first plant and 14.7 ± 6.0% at the second one revealed ODTS (grain fever) as shown in Table 4. The most frequent symptoms were fever, chest tightness, cough, chills, stuffy nose, sore throat, headache, muscle and joint pains. None of the members of the control group reported the occurrence of this syndrome. ODTS was most frequently found in the groups of unloaders (74.0 ± 8.4%) and facility operators (50.0 ± 9.4%). The average age of workers reported grain fever was 41.8 years at the first plant and 35.6 years at the second one, the length of service was 12.4 years and 4.4 years respectively (Tab. 4). Symptoms appeared in 66.7% of workers 3–6 hours after exposure (cleaning of grain or silo storage, loading of grain or silo etc.). The remaining 32.3% of workers experienced symptoms after a somewhat longer lapse.

We were also interested in the association between the history of ODTS and the occurrence of chronic bronchitis. In 47.9 ± 7.2% of workers of both plants with ODTS, this syndrome was associated with chronic bronchitis, while in 16.6 ± 5.3% with pneumosclerosis.

Chronic respiratory diseases. The results of our study revealed that the prevalence of chronic respiratory diseases was at the first place at the first plant and at the second place at the second plant (after cardiovascular pathology). Among them chronic bronchitis predominated,

Table 3. Prevalence of respiratory symptoms in workers engaged in animal feed production.

Respiratory symptoms	Prevalence							
	First facility				Second facility			
	Exposed workers (N = 121)		Controls (N = 27)		Exposed workers (N = 34)		Controls (N = 58)	
	AM	SD	AM	SD	AM	SD	AM	SD
Cough 3 months during the last 2 years	30.6[ab]	4.2	3.7	3.6	15.5	4.8	11.8	5.5
Cough with phlegm	34.7[ab]	4.3	3.7	3.6	22.4	5.5	14.7	6.1
Wheezing	42.1[ac]	4.5	11.1	6.0	14.7	6.1	8.6	3.7
Chest tightness	14.8	6.8	5.0	4.8	11.8	5.5	6.9	3.3

N - number of subjects for each group; AM - arithmetic mean; SD - standard deviation; [a] significantly greater compared to controls, $p < 0.01$; [b] significantly greater compared to exposed workers in the second facility, $p < 0.05$; [c] significantly greater compared to exposed workers in the second facility, $p < 0.05$.

Table 4. Demographics of workers with ODTS.

Facility (Exposed workers)	Workers with ODTS		Gender				Age (years)	Length of service (years)	Smoking		
			Male		Female						
	N	%	N	%	N	%			N	%	Years
First (N = 121)	48	39.7	18	14.9	30	24.8	41.8	12.4	15	31.2	12.3
Second (N = 34)	5	14.7	3	8.8	2	5.9	35.6	4.4	2	40.0	7.5

N - number of workers.

reaching 26.4 ± 4.0% at the first plant and 8.8 ± 4.8% at the second one ($p < 0.01$) (Tab. 5).

The stratified multifactorial analysis showed at the first plant significant relation ($\chi^2 = 5.47$, $p < 0.02$) between hazardous work conditions (dust exposure) and broncho-pulmonary diseases development and less connection with smoking ($\chi^2 = 2.00$, $p < 0.05$). No significant relations were found in both cases at the second plant.

Among workers of the first plant, 21.5% of persons with chronic bronchitis had length of service more than 10 years, 4.1% - 5–10 years, 0.8% - less than 5 years. At the second plant, the length of service of workers with chronic bronchitis was 5–7 years.

Bronchoscopy revealed the signs of inflammation of I/I-II stage by Lemoine [16], and atrophy of a mucous membrane of bronchi.

Lung function. Study of lung function revealed predomination of obstructive changes which were more distinct in exposed workers of the first plant. Spirometric indices clearly decreased with years of employment, as seen in Table 6. Obstruction of small bronchi was the early sign of respiratory troubles in exposed workers. At this stage, respiratory symptoms were minimal or absent. With increasing years of employment in animal feed production facilities, bronchial obstruction spread to middle and large bronchi. It led to general obstruction and respiratory insufficiency in 32.2% of workers of the first plant and 6.4% of the second one.

The prevalence of restrictive changes of lung function was similar at both plants, reaching 9.9% at the first plant and 5.6% at the second one.

Bronchial hyperresponsiveness. To test airway reactivity a standard methacholine challenge test was performed. The decrease in FEV_1 after the test with low doses of PC_{20} (provocation concentration - the dose required for 20% reduction of FEV_1) occurred more frequently among the workers of food department, where the work conditions were most unfavourable (Tab. 7).

Bronchial hyperresponsiveness was found in 74.7% of workers, more often among women (82.5±5.9%) than men (68.0±6.8%). No significant difference was found in the prevalence of positive challenge test between smoking and nonsmoking subjects. Statistical analysis did not show significant relation between duration of employment in animal feed production and bronchial hyperresponsiveness.

DISCUSSION

The obtained results indicate that workers exposed to large concentrations of organic dust and endotoxins at fodder production plants are under increased risk of work-related pulmonary disoders. Dust concentrations in both plants ranged from 0.8 mg/m^3 to 114.6 mg/m^3, endotoxin concentrations - from 0.031 ng/m^3 to 240.0 ng/m^3; that is in agreement with previous studies of different authors [4, 9].

Table 5. Prevalence of chronic respiratory diseases among workers of fodder production facilities.

Disease	First facility				Second facility			
	Exposed workers		Controls		Exposed workers		Controls	
	N	%	N	%	N	%	N	%
Asthma	1	0.8	0	0	0	0	1	1.7
Chronic bronchitis	32	26.4[ab]	0	0	3	8.8	2	3.4
Emphysema	29	23.9[ab]	0	0	2	5.9	1	1.7

[a] significantly greater compared to controls, $p < 0.01$; [b] significantly greater compared to exposed workers in the second facility, $p < 0.01$.

Table 6. Prevalence of obstruction changes of lung function.

Length of service (years) (Examined workers)	Prevalence of obstructive changes						General obstruction	
	Size of bronchi							
	Small		Middle		Large			
	N	%	N	%	N	%	N	%
First plant								
Less than 5 (N = 26)	7	26.9	3	11.5	4	15.4	1	3.8
5–10 (N = 26)	10	38.5	10	38.4	13	50.0	3	11.5
More than 10 (N = 59)	32	54.2	25	42.3	36	61.0	19	32.2
Second plant								
Less than 5 (N = 13)	3	13.0	2	8.7	4	17.4	0	0
5–10 (N = 31)	7	22.7	5	16.1	4	12.9	2	6.4

N - number of workers.

Table 7. Results of methacholine challenge test.

Total examined	Positive test								Total	
	PC_{20} (mg/ml)									
	6.25		18.75		75.0		300.0			
	N	%	N	%	N	%	N	%	N	%
Workers of Premix Department (N = 31)	8	25.8	10	32.3	1	3.2	1	3.2	20	64.5
Workers of Food Department (N = 56)	31	55.4	8	14.3	5	8.9	1	1.8	45	80.4
Total workers (N = 87)	39	44.8	18	20.7	6	6.9	2	2.3	65	74.7
Controls (N = 19)	0	0	0	0	0	0	0	0	0	0

The results of our study clearly indicate chronic and acute respiratory effects of animal feed exposure. The effects that were detected were: increased prevalence of respiratory symptoms, lung function changes, bronchial hyperresponsiveness, ODTS, chronic bronchitis.

The analysis of reported symptoms indicates cough and wheezing as predominant symptoms. The frequency of work-related symptoms found in the present work (from 11.8% for chest tightness to 34.6% for cough with phlegm) conforms the range reported by earlier authors for grain elevator workers [3], and farmers exposed to organic dust [21].

The results of this study show that predominant effects of fodder-production's dust exposure appear to be related to the clinical picture of chronic bronchitis, and toxic responses to dust. Several authors have suggested a possible role of endotoxin in the etiology of chronic bronchitis [22]. The prevalence of chronic bronchitis among the workers of animal feed production facilities was related to duration of employment, reaching 26.4% among the

workers of the first plant. This is in agreement with previous studies where a relationship has been found between the duration of employment in grain elevator and prevalence of chronic bronchitis [7, 24]. Asthmatic reaction does not appear to play a significant role in the animal feed industry.

Examination of lung function revealed obstructive changes in workers and their progressive aggravation with increasing length of service. Previous studies had shown that exposure to organic dust induced decrease in FEV_1 [8, 32].

ODTS was noted in 27.2% of workers of animal feed production. It exceeds the prevalence of this syndrome in previous studies: the prevalence of ODTS in Sweden was estimated between 6 and 19%, and in Finland as 13.6% [14]. Some authors have mentioned a possible causal role of endotoxins in the development of ODTS [23].

The frequency of positive reactions to methacholine challenge test in the present study (74.7%) was higher compared to the values reported by other authors for workers exposed to organic dust [12, 26].

Our results showed higher prevalence of respiratory symptoms among the workers of the first plant, where the work conditions were more unfavourable and the length of service was longer than at the second one. Among these workers, also lung function disturbance, bronchial hyperresponsiveness and ODTS were more frequently noted.

CONCLUSION

Workers in the Ukrainian animal feed industry are frequently exposed to dust and endotoxins levels in excess of national limits for grain dust (4 mg/m^3).

A comparison between animal feed workers and internal controls revealed work-related respiratory symptoms. Respiratory symptoms and toxic reaction were present in animal feed workers. The predominant symptomatic and lung function effects indicate a clinical picture related to chronic bronchitis. The prevalence of respiratory troubles was related to dust exposure more strongly than to smoking. Most of lung function variables were lower in the group of exposed workers than in controls. The examination of lung function revealed the obstructive changes. The prevalence of respiratory symptoms and lung function changes were correlated with the duration of employment in animal feed production. Obstruction of small bronchi and bronchial hyperresponsiveness were the early diagnostic signs of respiratory troubles in workers of animal feed production.

The aforementioned facts allow to conclude that the problem of influence of organic dust on the human organism is of importance in Ukraine and needs further studies in order to work out the arrangements for prophylaxis of occupational diseases. The health risk should be reduced by the implementation of protective measures, such as improving of ventilation, using of individual protective measures, hermetisation and mechanisation of the production process and improvement of medical survey of risk categories workers.

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