Arh. hig. rada toksikol., **30** (1979) suppl. pp. 939–947.

LUNG DISEASE DUE TO INHALATION OF ORGANIC DUSTS IN A STARCH INDUSTRY

L. FABBRI[1], C. MAPP[1], A. ROSSI[1], G. MORO[1] and A. PEZZINI[2]
Institute of Occupational Health, University of Padua[1] and Institute of Pathology, University of Verona[2], Italy

ABSTRACT

The results of a survey undertaken in 1975 to measure the prevalence of lung disease in workers employed in a starch industry are presented.

Out of a total of 661, 42 workers exposed to corn, feed, dextrin and starch dust were investigated by means of an E. C. S. C. qùestionnaire respiratory function tests (spirography, Dl_{CO} by the steady-state and single-breath methods, MEFV), mycological and serological studies, and chest-X-ray. Dust measurements were conducted at various work-stations (elevators, silos, packing areas): dust was found in concentrations between 3.8 and 55 mg/m^3.

The prevalence of chronic bronchitis (35.7%) and respiratory function impairments was higher in the exposed group than in a control group in the same factory.

Extrinsic allergic alveolitis (EAA) was diagnosed in 5 cases (11.9%), all with a mild respiratory function impairment. The mycological and serological studies confirmed the risk of EAA in the starch industry.

Recommendations are made to prevent further inhalation of dusts at certain work-stations.

Numerous respiratory diseases of workers exposed to organic dusts have been recognized[15]. Asthma, byssinosis and hypersensitivity pneumonitis have been reported in addition to chronic bronchitis. However, chronic exposure to organic dust will often lead to irreversible lung damage.

Several reports deal with grain workers, particularly in relation to farmer's lung[7] and chronic obstructive lung disease[8,16]. No reports are available on the effects of occupational exposure to organic dusts in the grain transformation industry and, in particular, in the starch industry. The only experimetal paper[13] concerns exposure of piglets to corn and starch particles suggesting that these dusts might be rather innocuous since no abnormal cell response in the tissue of the respiratory tract was observed. Van Den Berg[17] writes: "Starch dust is not normally considered harmful to the lungs, although it may aggravate lung conditions such as emphysema". Clinical and experimental data suggest the potential antigenic properties of starch particles[6,11,14].

The only industrial survey concerns cutaneous infections due to *Candida albicans*[2]. A rich flora has been demonstrated mainly in the first phases of the work cycle.

A starch industry provided an opportunity for a study of workers exposed to corn, dextrin, feed and starch dusts. This preliminary report is concerned with the chronic effect of such exposure on the lungs.

SUBJECTS AND METHODS

Out of a total of 661 workers employed in a starch industry, we examined 42 subjects exposed to organic dusts in the grain elevator and at the dextrin, feed and starch packing work-stations. A control group of 42 workers of the same factory, comparable by age (44 yrs), height (170 cm), duration of exposure (exposed: 15 yrs, control: 17 yrs), sex, and smoking habits was also examined. Of the exposed group, 88% were regular smokers, and of the control group 81%.

Definition of respiratory symptoms and measurements of lung function

The E. C. S. C. (European Carbon and Steel Community) questionnaire for chronic bronchitis and emphysema was used to record respiratory symptoms, smoking habits, past history of chest disease, and a detailed occupational history. Chronic bronchitis was defined as cough and phlegm for a minimum of three months in one year and for not less than two successive years.

In all subjects forced vital capacity (FVC), forced expiratory volume in one second (FEV_1) and maximal flows at 50% and 25% of FVC were measured using an OHIO 840 dry spirometer connected to an X-Y recorder (Honeywell 530) plotting volume with time, and to another X-Y recorder (Hewlett Packard 7045A) to plot flow versus volume.

The predicted normal values of lung volumes were derived from E. C. S. C. tables[9]. The normal values of Cherniack and Raber[3] were used for $\dot{V}_{max50}$ and $\dot{V}_{max25}$. The single breath diffusion capacity method was that of Cotes[5]. The inspired mixture contained 0.28% carbon monoxide, 12% helium, 20% oxygen, and 67.7% nitrogen. The transfer factor (Dl_{CO}) was divided by the alveolar volume (V_A) to obtain the transfer coefficient (K_{CO}), expressed in mmol CO $\times$ min^{-1} $\times$ $\times$ KPa^{-1} of alveolar CO. The predicted normal values were calculated from Cotes's formula[4]. Uptake of CO was expressed in per cent values of inspired carbon monoxide (Fico-Feco/Fico $\times$ 100). The inspired mixture contained 0.05% of carbon monoxide in the air.

Chest X-rays were taken of the whole population. The X-rays were read independently according to the ILO-classification[12], by two radiologists. A normal film has been recorded as 0/0. Category 0/1 was recorded if both readers considered 1 but recorded 0, or if one reader recorded 0 and the other 1/0 or more. Category 1 was recorded if both readers recorded 1/0 or more.

Site description

Shelled grain arrives at the elevator area where it is unloaded and cleaned of all undesirable foreign matter (Fig. 1). Dust and light chaff are removed by

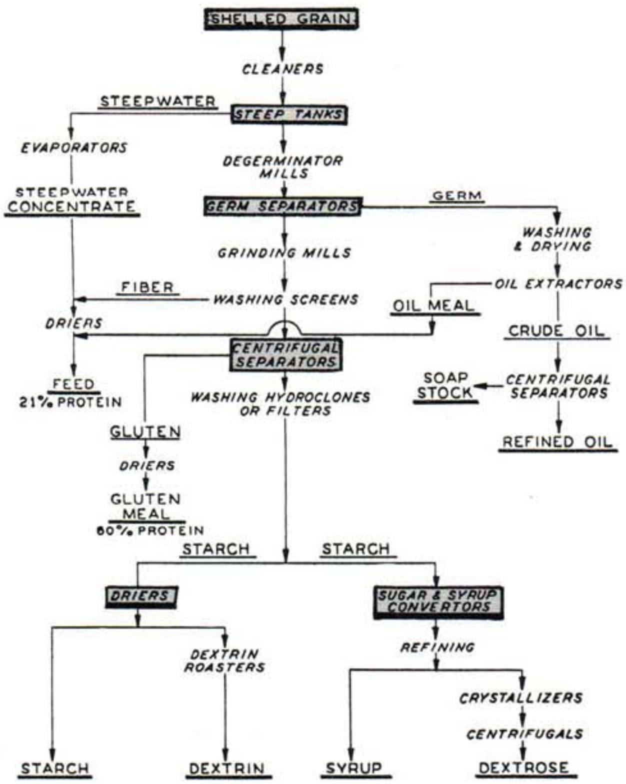

FIG. 1 – Flow diagram of the wet milling process.

aspiration. Prior to wet milling, the corn must be softened by a steeping process for 50 hours, in steep tanks with water containing about 2 000 ppm of SO_2, in order to achieve swelling and disperse all of the protein matrix. The milling process ensures a complete separation of the component parts of the corn kernel (germ, gluten and starch). The separated components are dried and then sent to the packing areas. The exposed men worked in the elevator, silos, packing and maintenance sections with a daily short-term, or continuous, exposure to organic dusts. As only a few workers were subjected to a continuous exposure over many years in the same work area, we studied the whole exposed group. The control subjects were chosen among unexposed workers at the same plant.

Airborne total and respirable dust

Samples were collected with a pump connected to a sampling head containing a cellulose 50-mm-diameter membrane filter with 0.45 μm pore size (mod. Asema). Area samples were taken at breathing zone level (about 1.5 metre above the floor). The flow rates were maintained between 15 and 20 litres per minute, throughout a sampling period of 30–60 minutes. The size distribution of the particles was established using a particle analyser (Climet CI-201), which classified the dust into five size categories (0.3–0.5, 0.5–1.0, 1–3, 3–5 and 5–10 μm). The samples were collected in the same positions of the gravimetric zones at an airflow rate of 6 to 7 litres per minute. The measurements were conducted by Dr E. Ricci of the Chemical Section of the Provincial Department for Hygiene, Ferrara, Italy.

Airborne fungi specification

Cultures were obtained by means of the open plate technique: plates containing Saboureaud and Czapeck culture media were exposed at various work stations for five minutes and then incubated for two or three weeks at room temperature. The isolated colonies were identified as to genus. No attempt at quantification was made. The specifications were done in the Mycrobiology Department of the Hospital of Verona (Prof. A. Bonomi).

Immunological data

The counter-immunoelectrophoresis method was used to detect circulating antibodies against standard hypersensitivity pneumonitis antigens. This test was performed in all the exposed subjects and in 17 subjects not employed at the same factory and not exposed to known sources of recognized causal agents of hypersensitivity pneumonitis. The specific antigens were provided by the Hollister-Stier Laboratories. The serum for *A. fumigatus* was concentrated to 1/3 of its volume before use.

RESULTS AND DISCUSSION

Dust was collected as general area samples obtained at different work sites. Table 1 lists the mean and range values of total dust concentrations to which the workers were exposed. Total dust concentrations reached a maximum of 55 mg/m^3 at the dextrin packing area. The mean values exceeded 20 mg/m^3 in all but the feed packing area. Even though the exposure of the subjects was not

TABLE 1
Total dust concentrations in the work areas.

Work area	Number of samples	Total dust concentration (mg/m^3)	
		Range	Mean
Corn silos	6	8.4–44.6	28.7
Dextrin packing	5	3.6–55.0	23.4
Feed packing	1	3.8	3.8
Starch packing	4	3.8–47.6	21.2

continuous, these values are still above both the 8-hour limit of 10 mg/m^3 and the STEL of 20 mg/m^3 given for nuisance particulates[1]. The size distribution of the dust from the various work areas was established using a particle electro--optical analyser. This showed that over 95% of the particles were smaller than 5μm, in all the work areas. These preliminary results regarding corn dust agree with those of Farand and Moore[10]. However, there are discrepancies between our data and the laboratory analysis of corn starch particle size. The quartz content of the corn was not measured, but Farand and More[10] report a percentage below 2%.

Table 2 shows a prevalence of respiratory symptoms and disease both in the exposed group and in the control. A significantly higher prevalence of winter morning cough and phlegm and of chronic bronchitis was found among the exposed workers. Dry cough and shortness of breath during work were comparable in the groups. No clear-cut episodes of shortness of breath without

TABLE 2
Prevalence of respiratory symptoms in the exposed and control groups.

Symptoms	Exposed group		Control group	
	N	%	N	%
Morning cough in winter	24	57.1***	6	14.3
Morning phlegm in winter	15	35.7*	5	11.9
Chronic bronchitis	15	35.7**	4	9.5
Wheezing	7	16.7	4	9.5
Dyspnea	6	14.3	10	23.8
Asthma	2	4.8	1	2.4
Dry cough and/or shortness of breath during work	10	23.8	7	16.7

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

wheeze, dry cough, fever and malaise occurring several hours after exposure were observed, so we can exclude clear episodes of acute allergic alveolitis. In the exposed group, none among the non-smokers and 40.5% among the smokers had chronic bronchitis. In the control group 12.5% of the non-smokers and 8.8% of the smokers had chronic bronchitis. There is a significant difference in the prevalence of chronic bronchitis (at the 1% level) between the exposed and the control workers. Table 3 shows a rise in the prevalence of chronic bronchitis with increasing length of service only in the exposed group, up to 50% over 20 years of exposure.

Table 4 summarizes the mean levels of the lung function measurements and shows a significantly higher residual volume and lower maximal expiratory flows in the exposed as compared with the control group. There is no difference between the two groups in FVC, FEV, CO uptake and transfer coefficient. Standardizing for length of service (Table 5), the differences in maximal

TABLE 3
Prevalence rate of chronic bronchitis in the exposed and control groups classified according to the length of service.

Years	Exposed group		Control group	
	N	%	N	%
<10	4	25.0	0	0.0
10–20	5	35.7	2	11.1
≥20	6	50.0	2	13.3
Total	15	35.7	4	9.5

TABLE 4
Mean values and standard deviations for pulmonary function measurements of the exposed and control groups.

Tests	Exposed group	Control group
VC (l)	4.3 ± 0.6	4.5 ± 0.9
FEV (l)	3.3 ± 0.6	3.6 ± 0.9
RV (l)	1.9 ± 0.6**	1.6 ± 0.4
$\dot{V}_{max\ 50}$ (l/sec)	3.7 ± 1.3**	4.9 ± 1.6
$\dot{V}_{max\ 25}$ (l/sec)	1.3 ± 0.6*	2.0 ± 0.9
F_{co} (%)	40.3 ± 5.0	38.4 ± 6.1
K_{co} (mmol × m^{-1} × KPa^{-1})	1.7 ± 0.3	1.6 ± 0.3

*$p < 0.05$
**$p < 0.01$

TABLE 5
Mean values and standard deviations for $\dot{V}_{max\ 50}$ and $\dot{V}_{max\ 25}$ of the exposed and control groups classified according to the length of service.

Years of service			Exposed group		Control group
$\dot{V}_{max\ 50}$	<10		4.5 ± 1.3		4.8 ± 1.5
	10–20		3.2 ± 1.1		5.4 ± 1.4
	≥20		3.6 ± 1.2		4.3 ± 1.9
$\dot{V}_{max\ 25}$	<10	I	1.7 ± 0.6	n.s.	2.4 ± 1.1
	10–20	II	0.9 ± 0.4	***	2.1 ± 0.6
	≥20	III	1.2 ± 0.5	n.s.	1.7 ± 1.0

Exposed group (I–III): $p < 0.05$; (I–II): $p < 0.001$
***$p < 0.01$

expiratory flows between the groups are confirmed only in the second class and no significant trend can be seen. In the control group we observed a decrease in $\dot{V}_{max25}$ due to increasing age, whereas in the exposed workers with more than 20 years of service we observed higher mean values in comparison with the 10–20 years class. The observation of an increasing prevalence of chronic bronchitis without a decreasing of maximal expiratory flows in the exposed group might be explained with a selection of the population: the exposed subjects with a lung function impairment might have terminated their employment.

Pin point opacities were observed in eleven exposed subjects but in none of the control. The profusion was classified as 0/1 in nine, and 1/0 in two subjects.

Only preliminary results of the study of the fungal flora (*Aspergillus niger, Aspergillus fumigatus, Penicillium, Cephalosporium, Cladosporium*) can be reported here. Four prevalent genera of fungi were identified. Among the genera *Aspergillus*, the species *A. fumigatus* and *A. niger* were identified. No difference was found among the individual work areas.

In order to evaluate the hypothesis that airborne flora produces a state of hypersensitivity to a particular antigen or initiates pulmonary mycosis, we conducted an immunological study to detect circulating antibodies against standard hypersensitivity pneumonitis recognized antigens.

Table 6 summarizes the results of the tests conducted with the counter--immunoelectrophoresis technique. The presence of precipitins for each *A. fumigatus* and *M. faeni* was observed in two exposed subjects. A positive reaction

TABLE 6
Number of positive results of serological tests in the exposed (N = 42) and control subjects (N = 17).

Species	All exposed (N = 42)	With pin-point opacities (N = 11)	With chronic bronchitis (N = 15)	Control subjects (N = 17)
Aspergillus fumigatus	2	2	2	0
Cephalosporium acremonium	0	–	–	0
Micropolyspora faeni	2	2	2	0
Sitophilus granarius	8	3	3	3
Thermoactinomyces vulgaris	8	4	4	2

to insect *Sitophilus granarius* and *Thermoactinomyces vulgaris* was observed in both groups. No positive reaction to *Cephalosporium acremonium* was obtained in either group. Positive reactions to *A. fumigatus* and *M. faeni* were observed in subjects with both respiratory symptoms and pin point opacities, whereas the number of positive tests to *T. vulgaris* increased in the group of symptomatic subjects. No difference was observed with *Sitophilus granarius* antigens.

Table 7 shows the results for five subjects affected by extrinsic allergic alveolitis obtained on the basis of radiological and immunological data and/or respiratory symptoms. All but one of the subjects had a long period of employment. In three subjects we observed an obstructive function impairment; with a reduction of FEV_1, only in one. In the other two subjects (2 and 5) we

TABLE 7
Characteristics of the five subjects with respiratory symptoms, pin-point opacities and specific precipitins.

Parameter	Subjects				
	1	2	3	4	5
Age	41	57	46	52	57
Years of exposure	8	28	18	28	30
Chronic bronchitis	+	+	+	−	+
Dry cough and/or shortness of breath	+	+	−	+	+
FVC (% of predicted)	80	83	93	100	72
FEV_1 (% of predicted)	46	89	86	109	90
$\dot{V}_{max}$ 50 (% of predicted)	25	100	72	78	66
$\dot{V}_{max}$ 25 (% of predicted)	18	75	40	66	47
F_{co} (%)	35	38	37	30	39
K_{co} (% of predicted)	109	84	109	103	81
Chest X-ray pin-point opacities	+	+	+	+	+
Precipitins	a,c	a,c	b,c	c	b
Bronchial provocation test	−	−	+	−	+

a = *M. faeni;* b = *A. fumigatus;* c = *T. vulgaris*

observed a significant reduction of FVC with borderline values of the transfer coefficient, suggesting a mild restrictive impairment. Positive reactions to the bronchial provocation tests with diluted specific antigens were obtained for *A. fumigatus* with a "flow response" after two hours, spontaneusly resolving within less than eight hours. No significant reduction in lung volumes, in symptoms or signs (fever, crepitant rales) were observed.

CONCLUSIONS

Long-term exposure to organic dusts in the starch industry causes chronic bronchitis and an obstructive impairment, even if smoking habits play an important additive role. Lung function impairment is better detected by measuring residual volume and maximum expiratory flows at low volumes.

The radiological, immunological and functional results allow us to hypothesize the development of chronic extrinsic allergic alveolitis in the exposed workers, even if chronic obstructive pulmonary disease appears to be the most common among the organic-dust-related pulmonary conditions. The mycological, immunological and functional studies suggest that *Aspergillus fumigatus* is one of the causal agents of extrinsic allergic alveolitis in the workers we studied.

Further studies should be done in order to understand the roles of *Micropolispora faeni, Thermoactinomyces vulgaris* and starch dust.

REFERENCES

1. *A.C.G.I.H.* Threshold limit values for chemical substances and physical agents in the workroom environment, 1977.
2. *Bulicrea, R., Ilie, M.* Dermatoze profesionale intro fabrica do amidon si glucoza. Igiena, **21** (1971) 307–310.
3. *Cherniack, R.M., Raber, M.B.* Normal standards for ventilatory function using an automated wedge spirometer. Am. Rev. Respir. Dis., **106** (1972) 38–46.
4. *Cotes, J.E., Hall, A.M.* The transfer factor for the lung normal values in adults. In: P. Arcangeli, ed. Normal Values for Respiratory Function in Men, Panminerva Medica, Torino, 1970, p. 327.
5. *Cotes, J.E.* Lung Function. Blackwell Scientific Publications, Oxford 1975, p. 244.
6. *Daim, D.W., Randall, J.L., Smith, J.W.* Starch in the lungs of new borns following positive pressure ventilation. Am. J. Dis. Child, **119** (1970) 218–220.
7. *DePico, G.A., Reddam, W., Flaherty, D., Tsiasis, A., Peters, M.E., Rao, P., Ramkim, J.* Respiratory abnormalities among grain handlers a clinical physiologic and immunologic study. Am. Rev. Respir. Dis., **115** (1977) 915–927.
8. *Dosman, J.A.* Chronic obstructive pulmonary disease and smoking in grain workers. Ann. Intern. Med., **87** (1977) 784–786.
9. *European Carbon and Steel Community E.C.S.C.* Tables des references pour les exames spirographiques, Luxemburg, 1971.
10. *Farand, J.P., Moore, C.F.* Dust exposure in the Canadian grain industry. Am. Ind. Hyg. Assoc. J., **39** (1978) 177–194.
11. *Grant, J.B. F., Davies, J.D., Jones, J.V.* Allergic starch peritonitis in the guinea pig. Br. J. Surg., **63** (1976) 669–673.
12. *International Labour Office.* International classification of radiographs of pneumoconioses. Occupational Safety and Health Series, Geneva 1970, no 22.
13. *Martin, S. W., Willoughby, R. A.* Organic dusts, sulfur dioxide and the respiratory tract of swine. Arch. Environ. Health, **25** (1972) 158–165.
14. *Michaels, L., Shah, M.S.* Dangers of corn starch powder. Br. Med. J., **2** (1973) 714–716.
15. *Parkes, W.R.* Occupational Lung Disorders. Butterworths, London, 1974, p. 392.
16. *Sheridan, D., Lidington, R.E., Tan, L., Deutscher, C.O., Barnett, D.G., Dosman, J.A.* The relationship between spirographic abnormalities and years of exposure in cereal grain workers (abstract). Am. Rev. Respir. Dis., **115** (1977) 244.
17. *Vandenberg, R.D.* Starch Industry. In: Occupational Health and Safety, International Labour Office, Geneva, Vol. II, 1347.