A SUMMARY OF THE HEALTH STATUS AND OCCUPATIONAL EXPOSURES OF GRAIN HANDLERS

Ralph Zumwalde

May 1976

INTRODUCTION

Traditionally, the objectives of dust control in grain elevators and mills were to reduce fire and explosion hazards and to reduce labor required for housekeeping. Fire and explosion control have always been emphasized along with the need for recommended work practices for dust control in elevators and mills. Recently, legislation has been enacted for the protection of workers' health and safety, the cessation of pollution, and the maintenance of a clean environment. This has come about through the Williams-Steiger Occupational Safety and Health Act of 1970 (Public Law 91-604) which required that standards be set for occupational exposures to hazardous substances including grain dusts. The requirements under this public law have re-emphasized the importance of dust control in grain elevators and mills.

DUST EXPOSURES FROM GRAIN HANDLING AND MILLING

Grain Elevators

Employment within grain elevators varies somewhat due to seasonal work but tends to range between 150,000 and 200,000. The grain harvested from American farms is generally sold and temporarily stored at one of approximately 12,000 grain elevator companies which are distributed throughout the United States, as shown in Figure 1. Storage capacity in these elevators range from a few thousand to millions of bushels. The harvested grain is delivered to the local grain elevator by truck where it is inspected and held for shipment to larger grain elevators or mills. In most instances grain is transferred in bulk from local elevators to large holding elevators or mills by means of rail or truck. Typically, the incoming grain is sampled for determination of moisture content, insects and foreign debris then dumped and weighed for storage. The grain is transferred from the dumping stations by underground conveyors to the leg or bucket conveying system which carries the grain up to the scale floor where additional weighing can be accomplished. If the grain contains excess moisture it is passed through a drying bin before storing. The station for centrally monitoring the bins and mixing the grain for shipment is located on the scale floor. From this station the grain is mechanically directed into specified bins by means of an open belt conveying system. This conveying system traverses the length of the elevator depositing the grain into the tops of the desired bins. The handling of grain at the elevator has been illustrated in Figure 2.

Because of potential problems with insect infestation it is sometimes necessary to add fumigants to the stored grain. This is often accomplished by dumping the fumigant directly on top of the stored grain or by adding it to the grain while it's being conveyed. Table 1 lists some of the chemical components commonly found in fumigants. Another approach to insect control is through constant aeration of the stored grain. Figure 3 demonstrates one of the more common methods of grain aeration..

Grain received from the harvest operations is generally unclean giving rise to unwanted foreign particulate material which may include grain bran, chaff, fiber stalks, stones, sand, broken cobs, metal, rust, weed seeds, pollens, mold spores, fungi, insect parts, fumigants and siliceous dust. The handling, cleaning and storage of this grain and its ultimate processing into animal feed, flour or other end products requires certain common operations which produce particulate waste. This waste has been estimated to be as much as 0.3 percent by weight of the bulk material handled. Much of this particulate waste has the potential to be respirable and tends to be generated each time grain is moved or transferred. The amount of dust generated by any transfer or grain conveyance (by chute, transfer belt, leg, open fall, or bucket elevator) is directly related to the degree of abrasion and attrition of the grain, the amount of previous handling, the characteristics of the transfer equipment, and the type of grain. Airborne dust exposures are often encountered during many of the common operations of loading, unloading, storage recycling, cleaning, drying, sizing, blending, separating and the application of fumigants.

Grain Mills

The bulk of the grain produced in the United States is processed as feed or milled into flour. Figure 4 illustrates the distribution and number of major mills found throughout the United States. Formula feed production is an example of a processing plant in the grain industry. Basic food ingredients, depending on the formula requirements, are corn, oats, barley, soybean meal, and wheat bran (a flour mill by-product). Minor formula additives include fish meal, bone meal, alfalfa, flax meals, molasses, tankage, screenings, and calcium and phosphate minerals.

Dusts are generated during the unloading of bulk grains and other dry additives found in formula feed production. In the production process, grain grinding and pelletizing are potential sources of respirable particulates along with the possible hazards of airborne fungi and residues of fumigants.

In the milling of grain to produce flour, the basic processes are the same throughout the industry. Various types of flour are produced with the aid of mineral enriching additives (i.e. calcium, phosphates, etc.), bleaching, and/or blending. Grain consigned to a modern mill is tested, graded and thoroughly cleaned. It is conditioned for milling in tempering bins and accumulated to flow in a continuous stream into the mill itself. The actual process of grinding, sifting, and separating takes only about 30 minutes from the time the grain enters the millstream until it is discharged as flour or mill feed. In that period, the grain and flour products undergo different operations until about 72 percent is finely ground into flour and the remainder into by-products used in animal feed.

In newer methods of milling, the flour is fractionated in granular form rather than pressed and broken as in a roller system. This fractionated flour flows into an air classifier, where swirling air funnels the large particles down while the smaller fines are lifted up and separated. High starch and protein fractions are thus concentrated in the small fractions. Within practical limitations, these methods permit the miller wider range in using different grades of wheat. A flow diagram of how flour is milled and fractionated is illustrated in Figures 5 and 6. Potential air contaminants are primarily particulates, fungi and residues of fumigants. Exposure to these contaminants would be most likely found in those areas of the mill where transfer and testing take place.

MEDICAL STUDIES

Studies on the adverse health effects to workers who handle grain or flour (Williams, et.al., Sloulas, et.al., Tse, et.al., Cohen and Osgood, Herxheimer, Duke, Dunner, Kleinfield, et.al., Dickie, et.al., Rankin, et.al.) have described a variety of clinical manifestations related to the environmental exposure. These have included allergic asthma, wheezing, febrile reactions to massive exposures or to re-exposure after a time interval (grain fever), fibrosis of the lung, rhinitis, conjunctivitis and allergic alveolitis. Allergic alveolitis has been distinctly associated with exposure to moldy grain and other vegetable materials; while a high evidence of chronic respiratory symptoms has been demonstrated by Hunter, Williams, et.al., Tse, et.al. and Rankin, et.al. with their studies on grain handlers.

Since grain dust is a complex mixture consisting of plant hairs, starch granules, spores of fungi, insect debris, pollens, animal hair, in addition to numerous insecticides at various stages of chemical degradation, the mechanism by which this dust induces the respiratory mucosal reactions, whether by chemical, mechanical or allergic is not yet clearly understood. One of the best known and documented symptoms, "farmer's lung," has been shown to be an allergic condition caused by exposure to damp moldy grain or hay. Studies performed by Dickie, et.al. and Smyth, et.al. have demonstrated in farmer's lung disease that the severity of the reaction increases with exposure and in later stages may be provoked by very slight re-exposures. The first symptom is usually a cough, followed later by wheezing, breathlessness, fever, weight loss and hemoptysis. The roentgenographic findings tend to illustrate that of interstitial pneumonitis. Individual hypersensitivity to molds and fungi or to their products seemed to be the decisive factor.

Grain fever is another acute reaction that has been noted in studies involving 216 grain handlers performed by Smith, et.al.. These studies showed a high incidence of pulmonary problems along with a general malaise, chills or fever. These problems were usually evident after high exposures to grain dust at the onset of starting work and upon returning to work after an absence of 2 or 3 weeks. Smith, et.al. has reported that these symptoms are similar to the condition known as "metal fume fever" and suggests that it may be a foreign protein reaction.

Some foreign components of the grains (fungi, insect debris, etc.) that the worker is exposed to may be the allergen responsible for the respiratory and conjunctiva reactions; likewise, the grain dust or flour itself could pose as a potential allergen and should be taken into consideration. Insect debris from wheat weevils (silophilus granarius) or mites (Tyroglyplus farinal) have been reported to be potent sensitizers (Morgan and Seaton). Similarly, fungi spores from species of penicillium, aspergillus and pullularia are also potential sensitizers (Reed). Studies performed by Lunn, Frankland, et.al. showed that two laboratory workers, who had spent considerable time each day handling grain infested by the wheat weevil (silophilus granarius), developed allergic responses to this insect varying from rhinitis and pruritus to marked asthma. These findings suggested that weevil protein present in mill dust could result in sensitization in those exposed continuously. Likewise, other studies (Grimm, Jimenez-Diaz, et.al.) have shown the existence of real sensitization due to just flour or grain. Cases of asthma were reported with positive intradermal and Prausnity-Kustner reactions on both grain handlers and bakers.

The most common fungi allergen found in populations of grain handlers has been Aspergillus. It was first reported by Leeuwen, et.al. in 1925, and later by Hansen as perhaps the most important fungal cause of respiratory tract disorders. Presumably, any species of Aspergillus may infect man, but those most frequently encountered are fumigatus niger, glaucus, and flavus, with fumigatus being far the most common. Aspergillus has been known to produce pulmonary aspergillosis in farmers and other workers exposed to grain dust. Typical forms of pulmonary aspergillosis consist of ulcerative bronchitis, bronchopneumonia, abscess and chronic granuloma formation. Studies by Hinson, et.al., Pepys, et.al. have shown that Aspergillus may also cause allergic reactions, resulting in episodic airway obstruction, pulmonary shadows and eosinophilia. Cultures of A. fumigatus from the sputum may indicate only coincidental contamination as demonstrated by Campbell, et.al., Henderson, et.al. and Wahner, et.al. Conversely, it has been shown by Belcher, et.al. that cultures from patients with pulmonary aspergillosis have often not yielded the fungus. Serum precipitins and skin tests are of diagnostic value in cases of aspergilloma and allergic aspergillosis but as demonstrated by Pepys, et.al., Campbell, et.al. and Longbottom, et.al. they are found also in other patients with lung disease.

A study by Williams performed on 502 grain elevator workers, showed that 54% of the workers had abnormal lung symptoms, including 35% with a cough. Clinical examination confirmed that 80% of the workers reporting a cough had a cough with "mucous, mucopurulent or, more rarely, blood stained sputum". Examinations also showed that 61% of those reporting symptoms had wheezing, 55% had mechanical irritation of the eyes and nose and 35% had a running nose. Only 40% of the workers showed x-ray evidence of pulmonary fibrosis and that the average lung capacity (1 sec. vital capacity) was less than 70% for workers with symptoms and for retired workers (80% was considered normal). In another study of 1554 grain elevator workers by Siemens, 37% of the workers had lung capacity less than 70%. The studies of both Williams and Siemens indicated that smoking increases the chance of lung disease for grain workers. Williams found that 41% of the smokers compared to 23% of the non-smokers had a cough, 17.5% of the smokers compared to 15% of the non-smokers had breathlessness and that wheezing was experienced by 21% of the smokers but only 10% of the non-smokers.

A later study of 68 grain elevator workers by Tse, et.al. found that 75% of the workers he studied had abnormal lung symptoms, including a cough with sputum and shortness of breath in over half of the smokers and 25% of the non-smokers. He found no correlation between positive reactions to the skin tests for allergy and lung symptoms and concludes that "hypersensitivity" is not important in the development of respiratory disorders in grain handlers. In a similar study of 300 grain elevator workers by Rankin, et.al. he likewise concurs with Tse that a chemical reaction such as in byssinosis rather than a hypersensitivity mechanism was the likely pathogenetic mechanism involved in producing the symptoms. Rankin does not exclude allergy as a mechanism inducing the respiratory symptoms in these workers. He did not find a correlation between symptoms or lung function abnormalities and precipitating antibodies to grain dust or fungal antigens, but he did find some positive correlations between skin reactivity to grain dust antigen and wheezing and abnormal flow rates or low lung volumes. Furthermore, he found a high incidence of skin reactivity to flax and mixed insects among the workers.

ENVIRONMENTAL EXPOSURES

The adverse effects of exposure to grain dust have been known to occur since 1713 according to the writings of Ramázzini as quoted by Hunter (1969). Ramazzini noted that almost all workers in granaries and barns that sifted and measured grain developed shortness of breath and rarely reached old age. Similar observations were noted by Thackrah (1832) when he wrote about the physical appearance of millers as being pale and sickly; most having defective appetites; and many being annoyed with morning cough and expectoration.

In 1935, Duke demonstrated that in flour mill workers the cause of asthma was an allergen derived from wheat. Through optical microscopy he determined that the morphologic structure of wheat hairs was probably responsible for the majority of cases of wheat asthma among millers. Heatley et.al. in 1944 observed a worker who had been employed for 8 years in an atmosphere of wheat dust while loading and unloading railroad cars. This worker suffered from severe dyspnea upon exertion and a dry cough. X-ray examination showed diffuse mottling in both lungs, with advanced fibrosis. Heatly et.al., reported that the grain dust contained 9.9% silica. Apart from this case little environmental data had been collected until a study reported by Williams et.al. (1964). In this study of 502 Saskatchewan elevator agents, it was found that wheat and oat dust levels ranged from 20 to 400 mg/m^3 during the dumping and transporting of grain at dump stations and beside weighing hoppers. In this same study air samples were collected with Greenberg-Smith impingers and high-volume air samplers for particle sizing and free silica determinations. Particle sizing was performed by light field optical microscopy using a Filar micrometer. The mean particle size of the airborne dust collected during the oat and wheat loading ranged from 1.7 to 3.1 microns. The size distribution of the particles indicated that 75% of the particles counted were 5 microns or less in diameter. Separations of organic and inorganic fractions were performed by floating the organic material off in chloroform. Free silica analysis was made with the Talvitie method. The free silica content of the total airborne dust was found to be 8.0% and 7.4% by weight of the oats and wheat dust, respectively. Only about one-third of this silica was in the organic fraction. In addition to the air samples, settled dust was collected from elevators handling wheat, oats, and barley and examined for the presence of fungi. Profuse growth of fungi were reported from all three dusts. Species of Aspergillus, Penicillium, Mucor, and Rhizopus were cultured.

In another study, Schrag reported the exposures of grain dust to grain elevator workers engaged in loading and unloading of grain into rail cars. Exposures varied between 11 and 25 mg/m^3 on an 8-hour time weighted average. A study was performed by Flesch et.al. (1975) of eight grain grain elevator companies in the Duluth-Superior region to determine airborne dust concentrations and the presence of fumigants. Eighty-five samples were collected to determine total airborne dust concentrations. Dust concentrations ranged from less than 1 to 118 mg/m^3.

Eleven of the eighty-five samples had concentrations greater than the present allowable OSHA threshold limit of 15 mg/m^3. Air samples were also collected for the determination of fumigants at various locations within the eight elevator companies. Samples were analyzed for carbon tetrachloride, ethylene dibromide, ethylene dichloride, methyl bromide, carbon disulfide, carbon bisulfide and phosphine. Only trace amounts were found, with all concentrations below the recommended OSHA threshold limit value. Prior to this study, OSHA (May, 1974) had inspected these elevators and found dust concentrations that ranged from 10.3 mg/m^3 to 125.5 mg/m^3.

In a recent study by Zumwalde et.al. (1976) of three grain elevators and one wheat flour mill, samples were collected of both air and settled dust for characterization. Air and settled dust samples revealed fragments of insects, pollens, plant hairs and various species of Aspergillus, Penicillium, Mucor, and Rhizopus fungi. Settled dust samples were also analyzed for trace metals (Cd, Co, Cr, Fe, Mn, Ni, Zn) by x-ray atomic absorption and for free silica by x-ray diffraction. Trace metal determinations appeared to be within expected range for these organic materials (Table 2) with free silica ranging from < 0.5 to 3.2% (Table 3). A particle size distribution was performed by optical microscopy on some of the airborne samples, indicating that 70% of the particles counted were less than 5 microns. Plant hairs were noted in most samples but did not appear to be within respirable sizes. The smallest plant hair diameter observed was approximately 5 microns.

All studies indicated that the main dust exposures at elevators occur: during the loading and unloading of grain, while grain is being conveyed within the elevator, around the drying and cleaning equipment, and during maintenance work on equipment and machinery. Through a study conducted by Midwest Research Institute (1971) it was concluded that the dust collection systems within most elevators were inadequate. In most instances cyclone collectors were utilized to control dust levels in the ambient air. The fractional efficiency curves of typical cyclones showed collection efficiencies of 80% or less for particles 10 microns or smaller. This investigator sampled for microorganisms in the grain dust, the cyclone dust and in the dust emitted from the cyclones. The results indicated numerous species of fungi in all dusts with the highest concentrations being found in the emitted cyclone dust.

DISCUSSION

Environment

The emphasis on environmental exposures and their effect on occupational health in grain and mills is many fold. Besides the many safety hazards (mechanical devices, dust explosions, etc.) grain handlers are exposed to an environment with potential diverse airborne pollutants. Their exposures to toxic fumigants (aluminum phosphide, methyl bromide, carbon tetrachloride, carbon bisulfide, carbon disulfide, ethylene dibromide, and ethylene dichloride) pose immediate health hazards. Listed in Table 4 are the potential adverse health effects resulting from exposures to these fumigants. In addition to fumigant exposures, investigators have reported the potential for high exposures to grain dust and their constituents during the operations of loading, unloading, conveying, drying, weighing, blending and sizing of grain. Excessive exposures are often a result of improperly designed, used, or absent dust collecting systems. This problem is accentuated due to a lack of mandatory respirator programs and improper respiratory equipment.

Studies in grain elevators performed by Flesch, et.al., Schrag, Williams, et.al., OSHA have reported total dust concentrations 20 times that of the present OSHA Threshold Limit Value of 15 mg/m^3. And, through the work of Williams, et.al., and Zumwalde, et.al. it has been shown that 70% of the airborne dust is less than 5 microns in diameter. Thus, a considerable amount of the airborne dust has the potential to be respirable. Concurrent with the airborne dust is the association of various species of Aspergillus which have been documented as causing respiratory problems.

Also, insect debris and plant fibers have been noted in airborne samples (Zumwalde, et.al.). These contaminants could contribute to a mechanical irritation or allergic response in the respiratory tract. In a early study by Heatley, et.al., it was reported that grain dust contained 9.9% silica, but this has been disputed in a later study by Zumwalde, et.al. in which the free silica content never exceeded 3.2%.

It is apparent from these studies that the occupational environment of grain handlers is complex. Further industrial hygiene studies are warranted to more precisely and accurately characterize the grain elevator and mill environment by quantitating and qualitating the airborne fungi, bacteria, insect debris, free silica, fumigants and their by-products, and other contaminants in the grain. These studies would include determination of the fraction of the airborne dust that is respirable and documentation of work practices that are employed to prevent potential health problems.

Medical

Studies on the adverse health effects to grain handlers (Williams, et.al. Skoulas, et.al., Tse, et.al., Rankin, et.al., etc.) have shown a variety of respiratory abnormalities. Many of these clinical manifestations (allergic asthma, grain fever, rhinitis, conjunctivitis and allergic alveolitis, etc.) have been demonstrated by many of the investigators in their studies of grain elevator and mill workers.

As a result of this clinical evidence further medical studies are warranted. Past medical studies seem to indicate that grain workers are a survival population. That is, those who became sensitized and developed symptoms due to their exposures probably left this occupation. These acute effects which resulted in abnormal lung functions should be further studied by randomly sampling a working population before and after a work shift and at the beginning and end of the week. Simultaneous with this study a complete environmental survey should be initiated for characterization of worker exposure.

The study by Rankin, et.al. concluded that if acute airway obstruction and ventialtion maldistribution develops or worsens from pre-exposure level, the subjects should be tested following pre-treatment with sodium chromoglycate. If an allergic pathogenetic mechanism is then confirmed, other studies to elucidate the nature of the immuno-reaction should be pursued. This can be accomplished through the physiologic and immunologic response of susceptible workers by confrontation with components of the grain dust, such as wheat, corn, barley, insect extract, and fungal extract.

Medical findings indicate that long term effects of exposure to grain dust among grain handlers should also be examined by a clinical, radiological, physiological, and immunological study at a 1-2 year interval. Particular emphasis should be placed on the detection of early signs of respiratory diseases such as asthma or chronic obstructive pulmonary disease, the frequency of disabling chest illness, allergic alveolitis, dyspnea, and the decline in pulmonary function with time (e.g. FEV_1 and DL compare with normal aging). The effects of age, length of employment, occupational history and smoking habits should be taken into account. A record assessment should be initiated to establish if allergic lung disease was a significant cause of disability or reason for changing jobs or retirement.

In addition, a diverse epidemiological study should be initiated to study grain handler populations in various parts of the country.

REFERENCES

1. Belcher, J.R., N.S. Plummer. Surgery in bronchopulmonary aspergillosis. British. J. Disease. Chest, 1960, 54, 335.

2. Campbell, M.J., Y.M. Clayton. Bronchopulmonary Aspergillosis. American. Rev. Resp. Disease, 1964, 89, 186.

3. Cohen, J.R., G.A. doPico, W.G. Reddan. Report on Grain Millers Survey Study (1974). unpublished, University of Wisconsin.

4. Dickie, H.A., J.R. Rankin. Farmer's Lung: An Acute Granulomatous Interstitial Pneumonitis Occurring in Agricultural Workers. JAMA, 1958, 167, 1069.

5. Duke, W.W. Wheat Hairs and Dust as a Common Cause of Asthma Among Workers in Wheat Flour Mills. JAMA, 1935, 105, 957.

6. Flesch, J., et.al. Hazard Evaluation Report on Environmental Exposures in Grain Elevators in Duluth-Superior Area. (unpublished)

7. Frank, R.C. Farmer's Lung: A form of pneumoconiosis due to organic dusts. Amer. J. Roentgenol, 1958, 79, 189.

8. Frankland, A.W., J.A. Lunn. Asthma Caused by the Grain Weevil. Brit. F. Industrial Medicine, 1965, 22, 157.

9. Heatley, T.F., K. Dalton, C.R. Rex. A Case of Silicosis Caused by Wheat Dust. JAMA, 1944, 124, 980.

10. Hansen, K. Bronchial Asthma Due to Moulds. Deutsche Arch. Klin. Med., 1932, 173, 1469.

11. Henderson, A.H., Allergic Aspergillosis: review of 32 cases. Thorax, 1968, 23, 501

12. Henderson, A.H., M.P. English, R.J. Vecht. Pulmonary Aspergillosis. Thorax, 1968, 23, 513.

13. Hernheimer, H. The hypersensitivity to flour of bakers' apprentices. Acta. Allerg., 1973, 28, 42

14. Hinson, K.F.W., A.J. Moon, N.S. Plummer. Bronchopulmonary Aspergillosis. Thorax, 1952, 7, 317.

15. Hunter, D. Diseases of Occupations, St. Pauls, London, 1969, 1073.

16. Jimenez-Diaz, C., C. Lahoz, G. Canto. The Allergens of Mill Dust: Asthma in Millers, Farmers and Others. Annals of Allergy, Nov.-Dec. 1947.

17. Keevwen, W.S., Z. Bien, W. Kremer, H. Varekamp. On the Significance of Small Spored Types of Aspergilli in the Etiology of Bronchial Asthma. Ztchr. Immunitats forsch, 1925, 44, 1.

18. Longbottom, J.L., J. Pepys. Pulmonary Aspergillosis: diagnostic and immunological significance of antigens and C-substance in Aspergillus fumigants. J. Path. Bact., 1964, 88, 141.

19. Lunn, J.A. Millworkers' Asthma: Allergic Responses to the Grain Weevil. Brit. F. Industrial Medicine, 1966, 23, 149.

20. Morgan, W.K., A. Seaton. Occupational Lung Disease. W.B. Saunders Company, Philadelphia, 1975.

21. Pepys, J. Immunopathology of Allergic Lung Disease. Clin. Allerg., 1973, 3, 1.

22. Pepys, J., R.W. Riddell, K.M. Citron, Y.M. Clayton. Precipitins Against Extracts of Hay and Moulds in the Serum of Patients With Farmer's Lung, Aspergillosis, Asthma and Sarcoidosis. Thorax, 1962, 17, 366.

23. Pepys, J., R.W. Riddell, K.M. Citron, Y.M. Clayton, E.I. Short. Clinical and Immunologic Significance of Aspergillosis Fumigatus in the Sputum. Amer. Rev. Resp. Dis., 1959, 80, 167.

24. Rankin, J.R., G.A. DoPico. W.G. Reddan. Report on Grain Millers Survey Study (1974). unpublished, University of Wisconsin.

25. Schrag, K.R. Dust Concentrations in Alberta's Grain Industries. American Industrial Hygiene Association Journal. Feb. 1972, 33, 100.

26. Siemens, quoted in Ginnold, R. Grain Elevator Occupational Safety and Health Problems. University of Wisconsin, May 1975.

27. Skoulas, A., N. Williams, J.E. Merriman, Exposure to Grain Dust: II. A Clinical Study of the Effects. J. Occup. Medicine, 1964, 6, 359.

28. Smith, A.R., L. Greenburg, W. Spiegel. Respiratory Disease Among Grain Handlers. Industrial Bulletin (Dept. of Labor, New York State) 1941, 20, 1.

29. Smyth, J.T., G.E. Adkins, M. Lloyd, C. Moore, E. McWhite. Farmer's Lung In Devon. Thorax, 1975, 30, 197.

30. Tse, K.S., P. Warren, M. Janusz, D.S. McCarthy, R.M. Cherniack. Respiratory Abnormalities in Workers Exposed to Grain Dust. Arch. Environ. Health, Aug. 1973, 27, 74.

31. Williams, N., A. Skoulas, J.E. Merriman, Exposure to Grain Dust: I. A Survey of the Effects. J. Occup. Medicine, 1964, 6, 319.

32. Walner, H.W., N.G.G. Hepper, H.A. Anderson, L.A. Weed. Pulmonary Aspergillosis. Annals of Internal Medicine, 1953, 58, 472.

33. Zumwalde, R.D., et.al. Environmental Characteristic of Three Grain Elevators and a Mill. (unpublished).

Table 1

CHEMICAL COMPONENTS COMMONLY FOUND IN FUMIGANTS

methyl bromide
carbon tetrachloride
carbon bisulfide
carbon disulfide
ethylene dichloride
ethylene dibromide
sulfur dioxide
petroleum ether
aluminum phosphide
malathion - Organophosphorous insecticide

Table 2

TRACE METAL DETERMINATION OF SETTLED DUST SAMPLES

COLLECTED IN THREE GRAIN ELEVATORS AND A WHEAT FLOUR MILL

Sample Number	Cd µg/g	Cr µg/g	Co µg/g	Fe µg/g	Mn µg/g	Ni µg/g	Zn µg/g
A	<0.8	<5.1	<3.6	0.25	37.5	<5.1	45.1
B	11.5	35.0	<3.4	2.54	32.1	<4.8	96.7
C	<1.4	<9.4	<6.6	0.69	19.8	<9.4	131.9
D	3.0	8.7	<4.9	1.51	28.2	<7.0	149.7
E	0.5	3.9	<2.2	1.01	66.4	<3.1	95.7
F	2.0	6.2	<2.2	2.07	50.5	<3.1	104.7
G	14.9	9.3	<4.3	5.15	119.8	7.4	198.1
H	36.7	11.2	<6.3	6.07	127.2	<8.9	357.1
I	<0.3	2.4	<1.3	1.35	17.7	<1.9	79.6
J	<0.5	3.6	<2.5	1.91	33.3	<3.6	182.8
K	<1.7	<11.0	<7.9	1.09	29.5	<11.3	132.2
L	1.5	<8.5	<6.0	2.43	81.9	<8.5	166.5
M	<1.3	<8.5	<5.9	0.07	35.6	<8.5	28.4
N	<1.5	9.9	<6.9	1.54	94.5	<9.9	1979.2
O	4.2	9.9	<6.9	1.20	127.6	<9.9	9.9

Table 3

PERCENT FREE SILICA IN SETTLED DUST SAMPLES

COLLECTED IN THREE GRAIN ELEVATORS AND A WHEAT FLOUR MILL

Sample Number	Percent Free Silica
A	ND
B	0.6
C	<0.5
D	0.6
E	<0.5
F	ND
G	3.2
H	1.5
I	<0.5
J	1.3
K	<0.5
L	<0.5
M	ND
N	1.3
O	<0.5

Table 4

POTENTIAL ADVERSE HEALTH EFFECTS AS A RESULT

OF EXPOSURE TO FUMIGANTS

Fumigants and/or Chemical Components	Health Effects	OSHA TLV Standard (June, 1974)
Aluminum phosphide (phosphine)	Feeling of coldness and pain in region of diaphram. Symptoms can include diarrhea, nausea and vomiting, tightness of chest and cough, headache and dizziness. Chronic poisoning is similar to that of phosphorus with intestinal upset, jaundice, loss of appetite as liver enzyme function is paralyzed.	0.3 ppm 0.4 mg/m^3
Carbon bisulfide and Carbon disulfide	Effects the nervous system; single exposures are characterized by narcosis and its sequelae. Symptoms of repeated exposures are nervousness irritability, indigestion, bizarre dreams, insomnia, excessive fatigue, loss of appetite and headache	20 ppm TWA 30 ppm ceiling 100 ppm/for any given 30 minute period
Carbon tetrachloride	Irritant to mucous membrane, depresses the central nervous system, causes effects on blood cells and metabolic changes. Acute poisoning usually causes gastrointestinal damage including liver and kidney injury. Death may result from respiratory failure.	10 ppm TWA 25 ppm ceiling 200 ppm/5 min. out of any 4 hr. period
Ethylene dibromide	Irritant to mucous membranes, vapor can cause depression of the central nervous system, pulmonary irritation, and hepatic and renal damage on single exposure.	20 ppm TWA 30 ppm ceiling 50 ppm/5min. out of any 3 hr. period

Table 4 (Continued)

POTENTIAL ADVERSE HEALTH EFFECTS AS A RESULT

OF EXPOSURES TO FUMIGANTS

Fumigants and/or Chemical Components	Health Effects	OSHA TLV Standard (June, 1974)
Ethylene dichloride	Vapor exposure can cause nausea and vomiting, repeated exposures can cause liver and kidney damage.	50 ppm TWA 100 ppm ceiling 200 ppm/5 min. out of any given time period
Methyl bromide	May cause death or permanent injury after very short exposure, it is a central nervous system depressent and is toxic to the liver. Can cause pulmonary edema.	20 ppm TWA 80 ppm ceiling
Malathion	Organophosphorous insecticide: Irritant to nose and conjunctiva. Inhalation of human cholinesterase (both tissue and blood).	15 mg/m^3