# Physical and Biological Characteristics of Grain Dust

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DUST is generated each time grain is handled. Traditionally, the objectives of dust control in grain elevators were to reduce fire and explosion hazards and to reduce the labor required for housekeeping. Recently, legislation has been enacted for the protection of workers' health and safety, the cessation of pollution, and the maintenance of a clean environment.

In general grain dust is considered more a nuisance than a hazard. However, evidence of direct health hazards to workers from inhaling grain dust has been ample. The health problems reported have usually resulted from handling moldy or heating grain and have been variously termed "farmers' lung disease" or "heating grain syndrome," as described by Dennis (1973).

Conventional dust control systems used by the grain industry include cyclone separators for the removal of dust from the air. The dust separated from air is termed cyclone tailing dust, whereas that not separated is exhausted from the cyclone to the atmosphere and is termed emission dust.

The performance of cyclone dust separators varies. In a study conducted by the Midwest Research Institute (1971), fractional efficiency curves of typical cyclones showed collection efficiencies of 80 percent or less for particles 10 μm or smaller. Thus, the general recommendation is that cyclone separators now used in the grain elevators be replaced by cloth or fibrous filters that are more effective in separating fine dust from the air.

Spores produced by the common grain storage molds are smaller than 10 μm and may be emitted into the atmosphere with the unseparated dust from a typical cyclone. Dust of this size is considered to be "respirable dust," and does not settle out of the air readily. Considerable information is available on the range of sizes of respirable dusts and on their rate of settling (Gregory, 1973; Hatch and Gross, 1964).

The purpose of this study was to examine the dustiness of grain and to determine some of the physical characteristics of grain dust and the extent to which mold spores, and possibly undesirable fungal metabolites, were concentrated in the dust separated from grain. Since the dust collected is frequently returned to the grain and moves with the grain through the marketing channels, it may be a factor in the wholesomeness of the grain. The dust emitted to the atmosphere has the potential of spreading mold spores that may contaminate other stored grain or growing crops.

## MATERIALS AND METHODS

### Grain Lots Handled

Samples of dust generated by typical grain handling operations were collected from four lots of corn and two lots of wheat.

**Lot 1.** Corn, 1974 crop, good condition, dried with ambient air to 14 percent moisture content (M.C.). This locally grown grain had minimum handling before the test. Dust was collected while the 42-tonne (metric) lot was transferred from one storage bin to another at the U.S. Grain Marketing Research Center (USGMRC) at a rate of 44 tonnes per hour. All tailing dust from the dust control system was collected and weighed. A sample of the dust emitted with the air discharged by the cyclone was also collected. An automatic spout sampler collected samples of the grain at regular intervals during transfer.

**Lot 2.** Corn, 1974 crop, good condition, dried with ambient air to 11 percent M.C. A 50-tonne lot transferred from one bin to another at the USGMRC at a rate of 52 tonnes per hour was handled and sampled the same as for Lot 1.

**Lot 3.** Corn, 1974 crop, mixture from several local sources, some visibly moldy, dried with ambient air to 12 percent M.C. We included this 15-tonne lot in the tests to obtain dust samples high in microbiological contamination. This corn was handled three times at the USGMRC. Grain and dust collections from each handling were made in the same manner as described for Lot 1. The first handling included three more dust collecting points than did the third handling. The second handling included a conventional, grain-cleaning operation. The dust from cleaning was collected along with the dust from handling. In this test, grain was sampled before it was cleaned. The third handling of this lot was the same as for Lot 1.

**Lot 4.** Corn, 1974 crop, grade 2, 14 percent M.C. Dust and grain samples were collected during a 30-min period while corn was loaded into two hopper cars at a Kansas sub-terminal elevator. Dust was collected by hand from the cyclone tailing dust stream. Grain samples were collected by an automatic spout sampler.

**Lot 5.** Wheat, 1974 crop, grades 1 and 2, 11 percent M.C. Wheat from two different growing areas was unloaded into a Kansas sub-terminal elevator from a hopper car (car A) and a boxcar (car B). All the tailing dust coming from a cyclone was collected and weighed. The grain was sampled by hand from a conveyor belt. Samples were identified as coming from car A and car B.

**Lot 6.** Wheat, unknown origin grown before 1971, 9 percent M.C. Less detailed evaluations were made on the dust from this lot of 68 tonnes of old wheat obtained from the Commodity Credit Corporation.

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TABLE 1. DUST COLLECTED AS RELATED TO GRAIN LOT AND HANDLING OPERATION.

| Lot no. | Grain | Handling operation | Dust collected* percent |
|---|---|---|---|
| 1 | Corn | Bin transfer | 0.129 |
| 2 | Corn | Bin transfer | 0.122 |
| 3 | Corn | Bin transfer, first handling† | 0.258 |
| | | Bin transfer, second handling‡ | 0.534 |
| | | Bin transfer, third handling § | 0.105 |
| 5 | Wheat | Car unloading | 0.007 |
| 6 | Wheat | Bin transfer | 0.009 |

NOTE:
*Weight of dust collected expressed as a percentage of total weight of grain.
†First handling had 3 more dust collecting points than third handling.
‡Corn was cleaned during second handling.
§Third handling was the same as for Lots 1 and 2.

TABLE 2. SIZE DISTRIBUTION OF CYCLONE TAILING DUST.

| Lot no. | Grain | Dust particles smaller than: | | | |
|---|---|---|---|---|---|
| | | 500 µm percent | 125 µm percent | 30 µm percent | 8 µm percent |
| 1 | Corn | 89 | 77 | 57 | 5 |
| 2 | Corn | 94 | 86 | 61 | 6 |
| 3* | Corn | 93 | 81 | 52 | 7 |
| 4 | Corn | 90 | 76 | 54 | 12 |
| 5Car A | Wheat | 78 | 33 | 17 | 3 |
| Car B | Wheat | 86 | 54 | 33 | 4 |

*Dust collected during third handling, after cleaning.

Sampling was done as for Lot 1 while the lot was dawn from a bin and returned to the same bin at a rate of 66 tonnes per hour.

### Test Procedures

We collected emission dust by sampling 1/300th of the air discharged from a cyclone at the USGMRC. Ten nozzles were mounted in a manifold that was connected to a standard high-volume air sampler. By properly aligning and spacing the collecting nozzles in the cyclone air discharge, we obtained approximately isokinetic sampling. Dust was collected on a 20- x 25-cm, type A fiberglass filter and weighed. Each sample of emission dust was analyzed for biological components.

For each test, we removed a 1-kg sample from the tailing dust by repeated full depth coring with a 6.3 cm (2.5 in.) tube. The classification of the cyclone dust into coarse and fine fractions was made with the methods and equipment described below.

We determined distribution of coarse particle sizes after 20 min of sieving on a Fisher-Wheeler* sieve shaker, using a U.S. standard set of No. 20-, 35-, 45-, 60-, 80-, and 120-mesh sieves. Duplicate samples of 100 g of wheat dust were sieved. To reduce aglomeration of the dust particles in order that accuracy of size separation would be good, we extracted the oil from duplicate 30-g samples of corn dust with petroleum either before the dust was sieved.

We further classified fine dust passing through the 120-mesh sieve by the sedimentation method developed by Whitby (1955), using equipment manufactured by Mine Safety Appliance Co. This method involves centrifuging a suspension of dust in a liquid at increasing speeds and noting the height of the resulting sediment column. Centrifuging was continued until all particles were settled. We used a microstirrer to disperse the dust in naptha before feeding the suspension on top of benzene, the sedimentation liquid.

We determined the density of the tailing dust by measuring the volume displaced by approximately 3 g of dust in a 50-ml pycnometer filled with benzene. Unsieved dust samples were oven dried at 103 °C for 1 hr, placed in the pycnometer, weighed, and covered with chilled benzene. The partially filled pycnometer stood for 20 min to permit wetting and settling of particles before it was completely filled with benzene. The combined weight of dust and benzene was recorded when the mixture was in equilibrium with the room temperature of about 23 °C. Specific gravity of the benzene had been previously measured at room temperature.

The biological components of the grain and dust were determined by use of the following procedure. To determine internal invasion of whole grain, we surface-disinfected the kernels by washing them 1 min in 2 percent NaOCl, after which we rinsed the kernels in sterile water. Then we placed 100 kernels in petri dishes containing malt-salt-Tergitol agar (4 percent NaCl and 200 ppm Tergitol NPX-Union Carbide Corp.). The plates were incubated at 25 °C until fungi could be identified and counted. We made dilution counts (mold counts) on grain or dust by grinding 50 g of grain or 5 g of dust in 500 ml of 0.15 percent water agar in a Waring Blendor at high speed. The suspensions were serially diluted by factors of 10 to an appropriate point, and replicate 1-ml portions of several dilutions were pipetted into petri dishes. We then poured malt agar containing 4 percent NaCl, cooled to 50 °C, into the dishes and swirled it to distribute the suspension. After incubation at 25 °C for 3 to 5 days, colonies were identified and counted. Results were expressed as number of colonies per gram of grain or dust.

## RESULTS AND DISCUSSION

### Dustiness of Grain

The total weight of cyclone tailing dust collected, expressed as a percentage of the weight of the grain, was considered a measure of relative grain dustiness (Table 1). Both the kind of grain and the handling operation affected the dustiness of the grain. When similar grains had the same handling, the percentage of dustiness was nearly equal. Lot 3 had three different handlings, one of which included cleaning, and the dustiness was quite different in each handling. Wheat dustiness was similar for both test lots and was almost inconsequential in comparison with corn dustiness.

### General Characteristics of Grain Dust

The size distribution of cyclone tailing dust is given in Table 2.

Particles smaller than 125 µm make up the dust that becomes airborne and is the fraction of major concern both in plant housekeeping and in meeting air pollution standards. These particles accounted for over 70 percent of the corn dust weight.

The dust fraction smaller than 8 µm includes the respirable fraction that is considered a factor in the health of workers. Corn dust contained a larger fraction of respirable dust than did wheat dust. In the samples from commercial elevators, the fine fraction in corn dust was

*Reference to a company or product does not imply approval or recommendation of the product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

TABLE 3. DENSITY OF UNSIEVED CYCLONE TAILING DUST.

| Lot no. | Grain | Average density g/cc |
|---|---|---|
| 1 | Corn | 1.47 |
| 2 | Corn | 1.48 |
| 3 | Corn | 1.47 |
| 4 | Corn | 1.50 |
| 5 Car A | Wheat | 1.55 |
| Car B | Wheat | 1.66 |

three to four times that in wheat dust. Particles larger than 500 μm were mostly wheat hulls or corn cob fragments, accounted for about half of the dust volume, and could be separated from grain by conventional grain cleaners.

Because both the collection and separation of dust were essentially air classification processes, the similarity of size distribution indicates a similarity in both the dust and the dust control systems for Lots 1-4. The difference between the size of wheat dust from car A and car B may have been due to differences in previous cleanings, since the dust from both cars was collected by the same dust control system.

The densities of unsieved tailing dust are given in Table 3. The Particle Atlas (1967) lists the densities of grain dust as 1.4 g/cc, and of starch as 1.53 g/cc. Higher densities in dust may be due to particles eroded from concrete bins where grain was stored or from the presence of field dust (soil) in the grain. These factors may account in part for the higher density of the dusts collected from the commercial elevators.

TABLE 4. PERCENTAGE OF SURFACE DISINFECTED KERNELS YIELDING VARIOUS FUNGI ON MALT-SALT-TERGITOL AGAR.

| | | Percentage of kernels with: | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Lot no. | Grain | Penicillium spp. | Aspergillus flavus | Aspergillus niger | Aspergillus glaucus | Rhizopus | Mucor | Fusarium and Cephalosporium | Alternaria |
| 1 | Corn | 9 | 2 | 0 | 1 | 0 | 0 | 73 | 2 |
| 2 | Corn | 10 | 0 | 0 | 1 | 1 | 1 | 60 | 1 |
| 3 | Corn | 10 | 7 | 7 | 38 | 1 | 8 | 43 | 1 |
| 4 | Corn | 28 | 15 | 7 | 17 | 1 | 1 | 11 | 2 |
| 5 | Wheat | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 91 |

Corn dust contained 1 percent to 2 percent oil, enough to make fine particles too sticky to be easily separated from grain by cleaning or segregated by sieving.

**Fungi in Grain and Dust**

Table 4 shows the percentage of kernels in the various lots internally invaded by fungi. Corn lots 3 and 4 contained moderate percentages of storage fungi, whereas the other lots appeared relatively mold free. Table 5 shows detailed data on the number of colonies of microorganisms per gram for three lots of corn and for dust samples separated from the three lots during handling at USGMRC. Colonies counted by the dilution technique (Table 5) generally grow from spores, so the data are considered to be an estimate of the number of viable spores per gram of material.

Fusarium (*F. moniliforme* Sheldon), *Cephalosporium*, and *Alternaria* are "field fungi" and do not reflect grain quality or storage history. The other fungi listed in the tables grow in grain primarily during storage; their presence indicates spoilage to some degree.

High populations of any organism may inhibit the development of others on the culture plates. Certain fungi may be present in the grain, even in rather high numbers, but be obscured or inhibited in the culture plates by other fungi. For example, *Penicillium* in the grain from Lot 3 seemed to increase with each handling. This apparent increase may have been related to apparently decreasing populations of the faster-growing fungus, *Mucor*, or possibly *Fusarium* and bacteria. The apparent absence of bacteria in emission dust from Lot 3 may have been related to the extremely high populations of *Penicillium*, which could have inhibited bacterial growth on the plates. Other examples of this phenomenon can be seen in the data of Table 5.

High populations of *Mucor*, such as in Lot 3, are not common in grain. Some of the grain in that lot had been stored for a short time at about 25 percent moisture content, which

TABLE 5. CONCENTRATION OF VARIOUS MICROORGANISMS IN CORN AND DUST REMOVED DURING ELEVATOR HANDLING.

| | Colonies per gram (thousands) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sample source and lot no. | Penicillium spp. | Aspergillus flavus | Aspergillus niger | Aspergillus glaucus and A. versicolor | Rhizopus | Mucor | Fusarium and Cephalosporium | Bacteria |
| Whole grain | | | | | | | | |
| 1 | 2 | -- | 1 | -- | 1 | -- | 15 | 100 |
| 2 | 10 | -- | - | - | - | 120 | 800 | 10,000 |
| 3 1st handling | 5 | -- | -- | -- | -- | 300 | 400 | 55,000 |
| 2nd handling* | 50 | 5 | 1 | -- | -- | 200 | 100 | 17,000 |
| 3rd handling | 600 | 3 | 1 | -- | -- | 60 | 30 | 10,000 |
| Dust collected | | | | | | | | |
| 1 | 500 | -- | -- | -- | 10 | 1,000 | 5.000 | 20,000 |
| 2 | 100 | -- | -- | -- | 100 | 3,000 | 17,000 | 50,000 |
| 3 1st handling | 4,000 | 1,000 | 1,000 | 1,000 | 200 | 20,000 | 20,000 | 25,000 |
| 2nd handling | 3,000 | 600 | 300 | 2,000 | 5 | 3,000 | 40,000 | 100,000 |
| 3rd handling | 3,000 | 200 | 400 | 1,000 | 200 | 4,000 | 30,000 | 25,000 |
| Dust emitted | | | | | | | | |
| 1 | 27,000 | 3,600 | 1,700 | -- | 200 | 500 | 18,000 | 100 |
| 2 | 90,000 | 15,000 | 1,500 | 10,000 | 300 | 3,000 | 15,000 | 50 |
| 3 1st handling | 450,000 | 90,000 | 60,000 | 90,000 | 600 | 75,000 | 30,000 | -- |
| 2nd handling | 300,000 | 20,000 | 12,000 | 100,000 | 400 | 8,000 | 80,000 | -- |
| 3rd handling | 100,000 | 20.000 | 8,000 | 300,000 | 1,000 | 17,000 | 110,000 | -- |

*Corn was cleaned during second handling.

TABLE 6. CONCENTRATION OF MOLD SPORES IN FIVE LOTS OF GRAIN AND IN DUST REMOVED DURING ELEVATOR HANDLING.

| | | Quantity of material | | | Colonies per gram (thousands)* | | |
|---|---|---|---|---|---|---|---|
| Lot no. | Grain | Grain (Tonne) | Collected dust (Kg) | Emitted dust (g) | Grain | Collected dust | Emitted dust |
| 1 | Corn | 42 | 52 | 840 | 2 | 1,500 | 33,000 |
| 2 | Corn | 50 | 64 | 950 | 130 | 3,200 | 120,000 |
| 3 | Corn | | | | | | |
| | 1st handling | 15 | 38 | 640 | 300 | 27,000 | 770,000 |
| | 2nd handling† | 15 | 79 | 930 | 250 | 8,900 | 440,000 |
| | 3rd handling | 14 | 15 | 760 | 660 | 8,800 | 450,000 |
| 4 | Corn | (‡) | (‡) | (‡) | 1440 | 6,000 | (‡) |
| 5 | Wheat | 147 | 11 | (‡) | 0.4 | 80 | (‡) |

*Field fungi, primarily *Fusarium* and *Cephalosporium*, are not included.
†Corn was cleaned during second handling.
‡Data not available.

probably accounted for the high *Mucor* population. Samples of cyclone tailing dust from Lots 3 and 4 contained *Aspergillus flavus* but did not contain detectable levels of aflatoxin.

The most obvious relationsip in Table 5 is the greater concentration of microorganisms in collected cyclone dust than in grain, and in emitted dust than in collected dust. This overall relationship is more easily seen in Table 6, which summarizes data on storage fungi only. During the three handlings of Lot 3 corn, neither the quantity of dust emitted from the cyclone nor its spore concentration varied greatly. The second handling, during which the grain was cleaned, produced a somewhat greater amount of emission dust and a very large amount of cyclone tailing dust. Two to three times more dust per tonne of grain was emitted from the handling of Lot 3 as compared to Lots 1 and 2.

Lots 4 and 5 were handled in a completely different way in different facilities, but the corn in Lot 4 appeared roughly the same microbiologically as that in Lot 3. Lot 4 contained more *Penicillium* and less *Mucor*, but the higher spore concentration in dust than in grain was still evident. The wheat contained much lower mold populations than did corn, as well as less total dust. This observation was confirmed by other data from different lots of wheat in good condition.

Table 7 shows the number of mold spores, per tonne of corn handled, in the dust from Lots 1-3. Although the total number of spores in dust collected from Lot 3 decreased with subsequent handlings, the emitted dust remained high in mold spore count. The data suggest that even with moderately mold-damaged grain, dust control cyclones put an extremely high number of spores into the atmosphere. With our relatively slow rate of grain movement in the elevator, up to 20-30 billion spores were released to the atmosphere every minute. A larger, high-speed facility handling moldier grain could easily multiply the rate of atmospheric discharge 10 times or more.

TABLE 7. NUMBER OF VIABLE MOLD SPORES, EXCLUDING FIELD FUNGI, IN DUST REMOVED FROM THREE LOTS OF CORN DURING ELEVATOR HANDLING.

| | | Mold spores (billions) per tonne of corn handled | |
|---|---|---|---|
| Lot no. | | Collected dust | Emitted dust |
| 1 | | 1.8 | 0.7 |
| 2 | | 4.1 | 2.3 |
| 3 | 1st handling | 70.1 | 33.2 |
| | 2nd handling* | 47.4 | 27.8 |
| | 3rd handling | 9.3 | 23.9 |

*Corn was cleaned during second handling.

From the dust size distribution data (Table 2) and the density measurements (Table 3) the number of particles in tailing dust was estimated to be $1.7 \times 10^9$ per gram. A mold spore concentration of $27 \times 10^6$ per gram (Table 6) is certainly a large number, but represents only one viable mold spore per 62 dust particles. The concentration of mold spores in the dust emitted by conventional dust control systems and in tailing dust that may be returned to the grain was one of the important findings of this research. Although these tests did not clearly demonstrate that repeated handling of grain would significantly reduce mold contamination, it is obvious that proper disposition of tailing dust would reduce in-plant and general environmental contamination.

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