Building a Grain Bin Dust Simulator: A model to measure workers' exposure of organic dust

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INTRODUCTION

Grain dust is a combination of various components, including small grain particles, insect parts, silica, bacteria, fungi, and mycotoxins (figure 1.). The size of these airborne particulates is a concern in that they can become deeply lodged in the respiratory tract. Exposure to grain dust can diminish overall lung function and give rise to respiratory diseases such as, asthma, organic dust toxicity syndrome (ODTS), chronic bronchitis, and hypersensitivity pneumonitis (Farmer's Lung). On the farm, grain storage and handling facilities are primary locations for workers to have high levels of grain dust exposure.

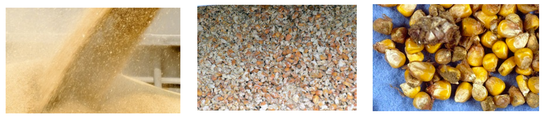

Figure 1. Some components of grain dust.

OBJECTIVES

The objectives of this research were to 1) understand current exposure level of the grain dust while farmers clean and unload their bins and 2) design a Grain Dust Simulator (GDS) to replicate the on-farm dust environment in a laboratory setting. By understanding workers' occupational exposure to grain dust, researchers can simulate environmental conditions (temperature, humidity, and air speed) in a controlled setting.

METHODS

There were two stages in this research. The first stage involved on-farm dust sampling at the grain bins, and the second stage designed a simulator to replicate the environmental conditions measured on the farms.

We visited farms to collect dust samples for characterization analysis and conduct real-time dust concentration measurement using DustTrak.

Both integrated and real-time samples were collected. The integrated samples provided the average concentration of total dust and respirable dust while farmers performed their normal duties at the grain bin. Real-time samples provided instantaneous concentrations of five different sizes of dust and how they changed during the farmers' working period. In addition, physical conditions, including air temperature, humidity, and the size of the grain bin, were also documented. Dust samples were collected at the breathing zone level. The sampling equipment is shown in the figure 2. In the lab, researchers designed and built a Grain Dust Simulator to replicate the grain dust environment found on-farms.

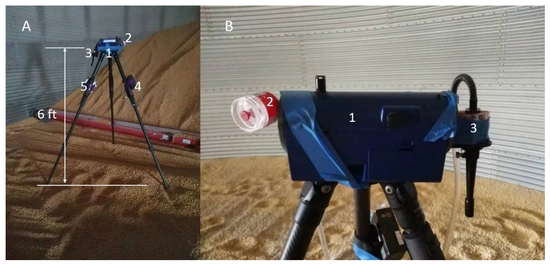

Figure 2. The Sampling Equipment on a Tripod

(A) is the view of the equipment on tripod: 1. TSI DustTrak 8533; 2. 37mm Three Stages Cassette with Filter; 3. 37mm Two Stages Cassette with Filter and Cyclone; 4 and 5 are Personal Sampling Pumps.

(B) is the front view of the sampling equipment on the tripod: 1. TSI DustTrak 8533; 2. 37mm Three Stages Cassette with Filter; 3. 37mm Two Stages Cassette with Filter and Cyclone

A small-scale bin model was designed following similar functions and dimensions as its farm-sized counterparts. The GDS is geometrically similar and aerodynamically equivalent to the farm grain bins; it contains similar ventilation and auger systems. The dust concentration data collected from farms were used to guide the environment simulation in the GDS, where the simulator was tested to replicate both dust concentration and size distribution found in the real environment.

RESULTS

On Farm Dust Sampling

Data collected on Ohio farms for two different crops, corn and soybeans, were at high concentration levels during the times farmers were unloading and cleaning their storage bins. The respirable dust concentration levels of corn storage ranged from 4.7 mg/m^3 to 5.9 mg/m^3 and the total suspended particles (TSP) concentration ranged from 4.6 mg/m^3 to 32 mg/m^3. Soybean storage bins had respirable dust levels of 9.5 mg/m^3 to 20.8 mg/m^3 and a TSP concentration range of 13.0 mg/m^3 to 48.0 mg/m^3. With both crops, respirable dust measurements were over the OSHA-recommended standard of 5 mg/m^3.

GDS System Development

The GDS operates within a controlled environmental chamber that was designed from an existing paint chamber in the OSU machine shop. The features of this chamber include: 1) An air conditioning system and room humidifier to control the chamber's temperature and humidity. The environment can range in temperatures from 20°C to 32°C, and a relative humidity from 30% to 90%; this is a sufficient range to cover the on-farm sampling records. 2) A ventilation system which is independent from the air condition system of the building. This ventilation system can help researchers control the environment dust concentration in the chamber and also clean the chamber between experiments. 3) The chamber contains a high-pressure air system, which is used to inject dust into the GDS. The air conditioning system, humidifiers, ventilation system, energy supply, and high-pressure air system are shown in the Figure 3. It contains a grain bin simulator, an auger system, a ventilation system, and a dust generator. The small-scale grain bin simulator showed in figure 4. The diameter of the small-scale grain bin simulator is 60 inches, and the total height of the grain bin simulator is 94 inches. The grain bin similitude contained two parts, the dust mix space is 6 inches height the volume is 9.8 ft^3. The dust environment space is 64 inches height, the volume is 78.5 ft^3. The grain bin simulator had a plexiglass window. This window allows researchers to monitor during the dust simulation experiment. The auger system in this grain bin with a speed control it could change the rotation speed and direction. The speed can control from -720 rpm to 720 rpm. The ventilation system has a dust fan which could simulate the fan in the real grain bin. The air flow rate of the ventilation system can be controlled up to 740 cfm. The ventilations system will also work with the dust generator to control the dust concentration in the grain bin.

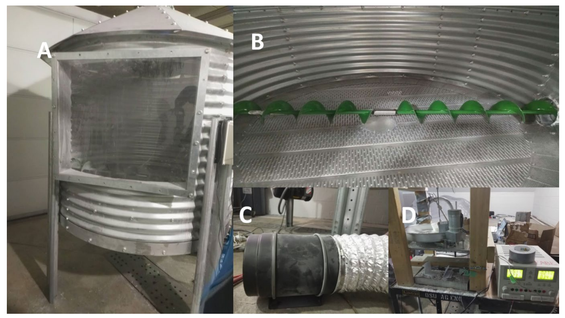

Figure 3. Equipment in The GDS system

(A). Grain Bin Simulator; (B). Auger System; (C). Ventilation System; (D). Dust Generator

In the testing work, the GDS system can simulate the dust concentration up to 150 mg/m^3 which could satisfy the requirement to simulate the on farm conditions. Depended on the dust concentration range from the on farm dust sampling, researchers are able to simulate the averages of typical dust concentrations in Ohio on-farm grain bins using the GDS.

CONCLUSIONS

Ohio farmers' exposure levels are very high. In corn storage bins, the respirable dust concentration ranged from 4.7 mg/m^3 to 5.9 mg/m^3 and the TSP concentration ranged from 4.6 mg/m^3 to 32 mg/m^3. In soybean storage bins, the respirable dust levels 9.5 mg/m^3 to 20.8 mg/m^3 and the TSP concentration range of 13.0 mg/m^3 to 48.0 mg/m^3. For corn and soybeans, the concentrations of both respirable and TSP were over the OSHA-recommended standards. (TSP= 10 mg/m^3; Respirable dusts = 5 mg/m^3)

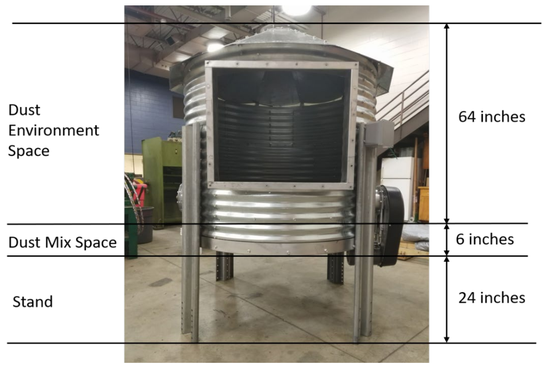

Figure 4. The Front View of the Grain Bin simulator

GDS is able to simulate the average dust level of the on-farm dusty environment. GDS can also simulate the effects of various environmental factors and operating conditions on dust concentration in grain bins. It will enable researchers to simulate the dusty environment in researcher's lab to investigate dust mitigation and personal protection in on-farm grain bins. In future work, researchers will test the efficiency of respiratory protection tested for their efficiency in these environments.

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