In-Depth Survey Report

Process Evaluation at Baker Boy

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Abstract

Researchers from the Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH) conducted an engineering control evaluation at Baker Boy, a producer of frozen baked goods, to evaluate their manufacturing processes regarding potential exposure to diacetyl and other food related flavorings; document the effectiveness of existing exposure control techniques; and identify areas where engineering controls may need to be developed or improved. A separate NIOSH team of industrial hygienists conducted an exposure assessment at this facility. The detailed results from the exposure assessment are included in a separate report. Personal sampling (from the exposure assessment study) and Video Exposure Monitoring (VEM) were conducted to evaluate potential risks during various tasks monitored during the engineering control survey. The task evaluated for diacetyl exposure was bulk mixing. Bulk mixing, cinnamon and caramel smear operations, and bench-top weighing were all evaluated for dust exposure using a real-time instrument, the HazDust IV. Personal sampling results indicated that the diacetyl concentration for the bulk mixing task was below the limit of detection, 1 µg/sample, during the engineering controls survey. The mean real-time HazDust IV dust concentrations for the tasks were: 1.38 mg/m^3 for bulk mixing, 2.95 mg/m^3 for cinnamon smear, 0.38 mg/m^3 for caramel smear, and 1.44 mg/m^3 for bench-top weighing.

Diacetyl concentration at Baker Boy was non-detectable for the bulk mixing task evaluated during the engineering control assessment survey. Real-time HazDust IV mean dust concentrations for all the evaluated tasks were below the respirable dust Permissible Exposure Limit (PEL) of 5 mg/m^3. However, because the HazDust IV is a non-specific instrument calibrated to a reference standard, the reported concentrations are relative, and there is some uncertainty of actual dust exposure concentrations. It may respond differently to dusts with optical properties different from Arizona Road Dust. Therefore, general and task-specific recommendations are included to control and reduce both diacetyl and dust exposures.

General Recommendations

1. Reduce exposure through engineering controls such as local exhaust ventilation (LEV) and work practices aimed at reducing dust and chemical vapor generation are primary preventive steps.

2. Clean spills immediately. Shovel large spills carefully into a waste bag. Workers might need to wear respiratory protection when cleaning spills.

3. Do not clean a dry spill with a brush or with compressed air. Vacuum or wet (when wet cleaning does not create another safety hazard) cleaning processes are recommended.

4. Enclose product mixers (i.e., ventilated booth) as much as possible and, if possible, provide seals on the lids and other access points to reduce the possibility of fugitive emissions.

5. Where possible, locate the working area away from doors, windows, and walkways to prevent drafts from interfering with the ventilation and spreading dust.

Task-specific Recommendations

1. Since weighing and pouring are often performed on a bench-top workstation, the addition of a ventilated booth designed to maintain an air velocity of 100–150 feet per minute (fpm) at the face of the enclosure for both the bench and the weighing area is recommended to control dust and chemical exposure.

2. A ventilated bag dump station, consisting of a hopper outfitted with an exhaust ventilation system, is recommended for tasks that generate significant amounts of dust (i.e., cinnamon smear task). This ventilated station is designed to pull dust away from workers as they open, dump bags of powder materials, and dispose of empty bags.

Introduction

Background for Control Technology Studies

The Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational safety and health research. Located in the Department of Health and Human Services, it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering and Physical Hazards Branch (EPHB) of the Division of Applied Research and Technology has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, EPHB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concept techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

Background for this Study

Researchers from NIOSH conducted an engineering control evaluation at Baker Boy, a producer of frozen baked goods, on July 13-16, 2009. The purpose of the site visit was to: conduct an exposure assessment for potential exposure to diacetyl and similar flavoring agents, and dust; document the effectiveness of existing exposure control techniques; and identify areas where engineering controls need to be developed or improved. Prior to this site visit, NIOSH researchers conducted a walk-through survey on June 30, 2009 at Baker Boy's North Dakota plant to identify the primary processes involved in the production of frozen baked goods, particularly processes that involve diacetyl and similar flavoring agents. The NIOSH

Industrywide Studies Branch (IWSB) of the Division of Surveillance, Hazard Evaluations, and Field Studies (DSHEFS) conducted an exposure assessment survey at the same time as the engineering control survey. The exposure assessment samples were used to evaluate engineering controls. The exposure assessment results of processes not evaluated by the engineers are reported separately.

Occupational exposures in the flavoring and food production industry have been associated with respiratory disease, such as bronchiolitis obliterans. Bronchiolitis obliterans is a rare and life-threatening form of obstructive lung disease characterized by significant permanent decreases in pulmonary function. It can progress to the need for a double lung transplant, or to death [California Occupational Safety and Health Administration 2009]. While the microwave popcorn industry has received the most attention both in the media and in the scientific community, the first occurrences of bronchiolitis obliterans in food production were observed in 1985 at a facility which made various flavorings for the baked goods industry [NIOSH 1985]. Severe bronchiolitis obliterans was observed in two men (both never-smokers and in their 20's) who held similar mixing jobs and blended corn starch and flour with various flavorings. During a NIOSH Health Hazard Evaluation (HHE), other workers who had held the same mixing job were evaluated for respiratory symptoms, and two additional cases were found (for a total of four out of the six mixers). A review of common ingredients listed diacetyl among other flavoring chemicals. A recent retrospective epidemiologic study found cases of bronchiolitis obliterans in workers who were employed in a chemical plant with exposures to diacetyl, acetoin, acetic acid, and acetaldehyde [van Rooy 2007].

Diacetyl is one of the main components in butter flavoring that gives it a buttery taste and has been identified as a prominent volatile organic compound (VOC) in air samples from microwave popcorn plants [Parmet and Von Essen 2002; Kanwal and Martin 2003; Akpinar-Elci et al. 2004; Kanwal et al. 2004; Kanwal et al. 2006]. It has several synonyms including 2,3-butanedione; biacetyl; 2,3-butadione; 2,3-diketobutane; dimethyl glycol; dimethyl diketone; dimethylglyoxal; and dioxobutane [National Toxicology Program 2009]. Diacetyl is used as a synthetic flavoring agent and aroma carrier in margarine, caramel, vinegar, dairy products, and is also naturally found in some foods. It is commonly used in the flavor manufacturing industry throughout the production of flavor formulations. Flavor formulations are then sold to downstream users for the production of flavored food products. Flavored food production involves the manufacturing of food and beverage products containing added flavor formulations or flavorings to enhance or modify the taste of the product. Examples of flavored food products include cake mixes, flour, beer, wine, margarines and soft spreads, cheese, candy, bakery products, crackers, cookies, ice cream, and frozen foods. The addition of concentrated flavorings, including diacetyl, is a cost effective way to impart the desired properties to manufactured food items.

Initial research concerning occupational exposure to flavorings focused on workers who directly produce flavorings or use them in the microwave popcorn industry. However, the employment figures for the food production industry suggest that a substantial number of workers have potential exposure to diacetyl and similar flavoring agents. Small scale weighing and handling of ingredients are common tasks in flavoring production, bakeries, dairy production, and snack food manufacturing. Weighing both dry and wet food ingredients can lead to worker exposure primarily through the scooping, pouring, and dumping of these materials. Ingredient mixing is also a source of potential exposure, depending upon the work practices employed when dumping dry ingredients (which may produce visible airborne dust), pouring wet ingredients into the mixer, and opening and closing the mixer lid. A recent survey at a commercial bakery showed that mixer operators were exposed to diacetyl when they measured and added an artificial butter flavor to a dough mixer [Eastern Research Group 2008a; Eastern Research Group 2008b]. In addition to the bakery industry, respiratory issues have been anecdotally reported for cheese production, yogurt, and potato chip manufacturing [Alleman 2002].

NIOSH is continuing diacetyl-related research through engineering control assessments, toxicological studies, respiratory protective equipment program evaluations, medical surveillance, and exposure assessments. NIOSH is evaluating occupational exposure to diacetyl in industries such as dairy/cheese processing, chocolate manufacturing, baked goods, frozen food, and other identified manufacturing sectors with potential for diacetyl exposure. However, the potential for both exposure and disease in the flavored food production industry still remains largely unstudied. There are few data documenting occupational exposures in flavoring and food manufacturing. With the lack of occupational exposure limits for a majority of the flavoring chemicals used in food production, the development of exposure control guidance is critical to help reduce the risk of flavoring-related obstructive lung disease. The Flavoring and Extract Manufacturing Association (FEMA) reports that of the more than 1,000 chemicals considered to be potential respiratory irritants or hazards, only 46 have established Permissible Exposure Limits (PELs) [FEMA 2004]. As a safe level for diacetyl is currently unknown, protecting workers from flavorings-related lung disease requires limiting exposure through use of the hierarchy of controls. One representation of this hierarchy can be summarized as follows:

- Elimination
- Substitution
- Engineering controls
- Work practice controls
- Personal protective equipment (PPE) [NIOSH 2003; Kreiss 2007].

The idea behind this hierarchy is that the control methods at the top of the list are potentially more effective, protective, and economical (in the long run) than those at the bottom. Following the hierarchy normally leads to the implementation of inherently safer systems, ones where the risk of illness or injury has been substantially reduced. Additionally, new diacetyl substitutes, such as 2,3-

pentanedione, are being used in production with little or no toxicological information. Until more is known, diacetyl substitutes should not be assumed safe.

Plant and Process Description

Baker Boy is a wholesale bakery manufacturer located in Dickinson, North Dakota. The 85,000 square foot facility is separated into two production areas: A and B. Area A includes dough sheeting/lamination, bread/buns production, cookie and muffin production, and mini cake loaves. Area A is also equipped with 12 double rack convection ovens. Area B includes the manufacturing of frozen dough buns/bread, dough sheeting/lamination that can be used to produce doughnuts, and a variety of other frozen dough products. Area B has doughnut fryers in which a variety of yeast raised and cake doughnut dough are fried.

The facility operates 24 hours per day, 7 days a week. There are over 200 plant employees and 70 office, warehouse, trucking, sales, and maintenance employees. A typical shift consists of approximately 50 production employees. Producing over 30,000 cases of product each week, Baker Boy manufactures over 400 varieties of bakery products in frozen dough, pre-fried, partially-baked, and fully baked forms. The use of flavorings, especially flavorings containing diacetyl, in Baker Boy products is only a small fraction of the business. A butter and vanilla flavoring was the only flavoring used at the time of the site visit. Diacetyl was not listed as an ingredient on the flavoring label. At the time of the survey, Baker Boy did have a respiratory program in place.

Description of Processes and Controls

The production of the bread and bakery products consists of common steps, such as weighing and mixing ingredients, proofing the dough (i.e., increasing the dough size), baking, cooling/freezing, and packaging [Hui 2007]. Typical ingredients for some of these processes include: flour, vegetable shortening and oil, sugar, yeast, eggs, ice, and flavorings. The dry ingredients are stored in closed plastic storage bins until ready to use. Employees at Baker Boy manually weigh and add sugar, salt, dry malt, all-purpose dough conditioner, and other ingredients to the mixer. Dough conditioners are designed to improve the quality of the flour, freezing capabilities, and dough volume. Flour is automatically added to a vertical high speed mixer from a flour silo. When the mixing is completed, the dough is tipped into a divider [The Federation of Bakers 2002; South Yorkshire GCSE Online Materials 2009]. From the divider, the dough is mechanically shaped and weighed. Seasonings (i.e., sugar, flavored smears) are added to the dough, and the dough is placed into baking pans/trays onto a conveyor belt. The pans/trays are placed on racks and moved into a proofing room, which is temperature and humidity controlled. After the dough has increased in volume, it is baked and then placed into the freezer to later be packaged. This survey focused primarily on processes that either used flavorings or generated dust during particular tasks, such as bulk mixing, cinnamon smear, caramel smear, and bench-top weighing.

Bulk mixing

In Area A, bulk mixing was evaluated because the process used various powders and involved bench-top weighing. The process began with the automated transfer of a flour mixture from a silo to a large (four feet diameter) mixing vat on wheels. While the flour was mixing, a worker weighed dry ingredients on a bench-top scale into a five-gallon bucket. The dry ingredients consisted of all-purpose dough conditioners, salt, dry malt, and sugar. After mixing the dough, the worker rolled the vat from under the silo to add ice and the five-gallon bucket of dry ingredients into the vat. The vat was wheeled to an adjacent mixing area and mixed until the ingredients were well blended. Before the process ended, the worker stopped the mixer and reached into the vat for a sample of the dough for a temperature reading. The vat was moved into a nearby area for production of baguettes.

Cinnamon smear

In Area B, the cinnamon smear operation was evaluated because it used a butter and vanilla flavoring along with various dusty compounds, such as cinnamon and powdered sugar. The opening, dumping, and disposal of powdered material frequently creates occupational dust exposures [Heitbrink and McKinnery 1986; Cooper and Gressel 1992]. The cinnamon smear is used for sweet roll production. The process began with powdered sugar which was manually dumped from a 50 pound (lb) bag into a medium sized (three feet diameter) mixer. The worker pressed a control to automatically close the lid and turn on the mixer. The worker then opened the lid of the mixer to add a pre-weighed five-gallon bucket of cinnamon located on the workstation. After the cinnamon was added, additional powdered sugar, butter and vanilla flavoring, pastry flour, and starch were added to the mixer. Once the ingredients were thoroughly mixed, two additional 50-lb bags of powdered sugar were added to the mixer. Water and soybean oil were also manually added to the mixer. Throughout the cinnamon smear operation, the worker would stop the mixer, open the lid, and scrape the sides and beaters before continuing with the recipe. Two five-gallon buckets that contained an undisclosed liquid mixture were added along with a fourth 50-lb bag of powdered sugar and a five-gallon bucket of soybean oil. When mixing was complete, the vat was covered in plastic wrap and transferred to another process area.

Caramel smear

Like the cinnamon smear, the caramel smear is used for sweet roll production. Baker Boy makes three different caramel smears. Of the three different formulations, heavy whipping cream and light brown sugar are the common ingredients. The caramel smear operation was evaluated because it was located in the vicinity of the cinnamon smear mixing process, which generated a considerable amount of dust. First the cream mixture was manually poured into a medium sized (three feet diameter) batch mixer called a liquefier. Then the cream mixture was mixed until thickened into caramel. The worker then poured the caramel product into small buckets and used a mallet to manually close the lids.

Bench-top weighing

Studies in bakeries have shown that the workers with the highest exposure to dusts (commonly from flour) are those who perform weighing and mixing tasks [Elms et al. 2003]. In Area B, the worker scooped dry ingredients from a storage bin into a five-gallon bucket located on a weighing scale. The process was repeated several times with various powdered ingredients until the recipe was completed.

Occupational Exposure Limits and Health Effects

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH investigators use mandatory and recommended occupational exposure limits (OEL) when evaluating chemical, physical, and biological agents in the workplace. Generally, OELs suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Combined effects are often not considered in the OEL. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus can increase the overall exposure. Finally, OELs may change over the years as new information on the toxic effects of an agent become available.

Most OELs are expressed as a time weighted average (TWA) exposure. A TWA exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short term exposure limit (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. The U.S. Department of Labor OSHA PELs [CFR 2003] are occupational exposure limits that are legally enforceable in covered workplaces under the Occupational Safety and Health Act. NIOSH recommendations are based on a critical review of the scientific and technical information available on the prevalence of health effects, the existence of safety and health risks, and the adequacy of methods to identify and control hazards [NIOSH 1992]. They have been developed using a weight of evidence approach and formal peer review process. Other OELs that are commonly used and cited in the U.S. include the TLVs® recommended by the American Conference of Governmental Industrial Hygienists (ACGIH®), a professional organization [ACGIH 2010]. ACGIH TLVs are considered voluntary guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards." Workplace environmental exposure levels (WEELs) are recommended OELs developed by the American Industrial Hygiene Association (AIHA), another professional organization. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2007].

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers are required to comply with OSHA PELs. Some hazardous agents do not have PELs, however, and for others, the PELs do not reflect the most current health-based information. Thus, NIOSH investigators encourage employers to consider the other OELs in making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminating or minimizing identified workplace hazards. This includes, in preferential order, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection).

Exposure Criteria

Dust

For respirable dust, the OSHA PEL is 5 milligrams per cubic meter (mg/m^3). There is no NIOSH recommended exposure limit (REL) for respirable dust. The ACGIH TLV for respirable dust is 3 mg/m^3.

Diacetyl

Exposure to diacetyl can occur by inhalation or skin contact [Acetoin and Diacetyl 2008]. Although, listed as a high priority chemical by FEMA, there is no OSHA PEL or NIOSH REL for diacetyl [Martyny et al. 2008]. Currently, work is being conducted by NIOSH to develop an REL for diacetyl [NIOSH forthcoming].

Methodology

Laboratory Data and Analysis

Personal, area, and bulk samples from Baker Boy were collected as part of the exposure assessment. Bureau Veritas North America, Novi, Michigan, analyzed the air samples with the OSHA Diacetyl and Acetoin Method 1013 [Acetoin and Diacetyl 2008]. The OSHA Diacetyl and Acetoin Method 1013 requires that air samples be collected by drawing workplace air through two sampling tubes, containing special dried and cleaned silica gel, connected in series. All SKC Pocket Pumps (SKC Inc., Eighty Four, PA) were calibrated and set at a nominal flow rate of 0.05 liters per minute (L/min) which is the standard flow rate for diacetyl sampling. Pumps were calibrated using a standard flow meter (Bios DryCal DC-LITE, Model DCLM REV.

1.08, BIOS, Butler, NJ). Sample results were reported in micrograms (µg) of analyte per sample. Analytical results were converted to an airborne concentration by dividing by the air volume associated with the sample (mg/m^3), then converting to parts per million (ppm) by volume standard temperature and pressure using the gram molecular weight of the analyte at standard temperature and pressure (Equations 1 and 2 below). The data were tabulated in Microsoft Excel (2003, Microsoft Corporation, Redmond, WA). The limit of detection for diacetyl was 1 µg/sample.

Equation 1:

$$C = \frac{m}{V}$$

Where

C = concentration, mg/m^3

m = mass, mg

V = volume, m^3

Equation 2:

$$C_{ppm} = \frac{C_{\mathrm{mg/m^3}} \times 24.45}{MW}$$

Where,

C_{ppm} = concentration, ppm

MW = molecular weight, 86.09 [Lide 2008]

Video Exposure Monitoring Test

Video Exposure Monitoring (VEM) is an exposure assessment technique in which real-time monitoring devices (e.g., photo-ionization detectors and dust monitors) are synchronized with video of the work activity. The product of VEM is a video of the work activity with a graphical presentation of exposures concentrations which correspond to the job task displayed on the video. VEM aides in the identification of work practices that can contribute significantly to overall exposure patterns by giving a visual display of work activities and the corresponding real-time monitoring values [Gressel et al. 1988; Gressel et al. 1993]. With this exposure assessment tool, both management and employees can be visually shown which activities have the highest exposure concentrations and can therefore benefit from a change in the work practice, installation of engineering controls to mitigate the exposure, or the use of PPE [Gressel et al. 1993]. Video exposure monitoring involves filming the task or work process of interest and simultaneously measuring the worker's inhalation exposure to dust using a real-time dust monitor.

Equipment

VEM was used to determine when dust was generated and which specific tasks or tools were major contributors to the overall exposure. These measurements were collected on workers performing mixing and weighing operations in order to determine the relative exposure caused by different tools and processes. A HazDust IV hand-held aerosol photometer (Environmental Devices Corporation, Plaistow, NH) measured the dust concentration. It operates on the principle of near-forward light scattering of infrared radiation. It immediately and continuously measures the concentration of airborne dust particles and displays the result in mg/m^3. The HazDust IV has an internal air sampling pump that is controlled by a microprocessor. The instrument has a detached sensor that can be positioned near the worker's breathing zone. OSHA-defined inhalable, thoracic, and respirable interchangeable sampling heads can also be added to the sensor. In past studies, the thoracic sampling head was used to collect dust measurements during the engineering control surveys. Therefore, for this study, the HazDust IV unit was outfitted with a thoracic sampling inlet. Total dust and respirable dust were also collected as part of the exposure assessment. An in-line 37 millimeter (mm) filter cassette was simultaneously collected and analyzed with gravimetric methods. The HazDust IV can detect particle sizes and dust concentrations from 0.1 to 100 micrometers (µm) and 0.01 to 200 mg/m^3, respectively. The HazDust IV is calibrated with the NIOSH Method 0600 using Arizona Road Dust test dust; it does not differentiate between types of dust (e.g., cinnamon and flour) and may respond differently to dusts with optical properties different from Arizona Road Dust. This may cause some uncertainties of the actual dust concentrations.

Procedure

The HazDust IV instrument was spanned and programmed according to manufacturer's instructions each sampling day. Verbal consent was obtained from each employee prior to participating in the sampling program. The HazDust IV was placed on the worker during the bulk mixing, cinnamon smear, caramel smear, and bench-top weighing operations to measure dust concentrations. The sampling head of the HazDust IV was positioned near the worker's breathing zone. During the completion of the work tasks, the worker was videotaped. The HazDust IV recorded data in one-second intervals for the bulk mixing operation and in 10 second intervals for the cinnamon smear, caramel smear, and bench-top weighing operations. Data from the instrument were downloaded to a computer and analyzed using Microsoft Excel.

Results

Laboratory results from the exposure assessment survey indicated that no diacetyl was detected during the bulk mixing task. The real-time data did show some peak dust exposures during bulk mixing, cinnamon smear, caramel smear, and bench-top weighing. Figures 1 through 4 in the Appendix show the HazDust IV dust concentrations of each operation. Table 1 in the Appendix displays the real-time mean and peak dust concentration for each job category. Tables 2 through 5 in the Appendix list the job task with corresponding mean HazDust dust concentration. The real-time data results are reported as Arizona Road Dust.

Bulk mixing

The overall mean dust concentration for the bulk mixing tasks was 1.38 mg/m^3 for a five-minute HazDust sample. Dumping of ingredients, vat mixing of ingredients, bench-top weighing, and moving vat to next production area were among the tasks evaluated. Dumping of ingredients, bench-top weighing, and moving the vat had the lowest mean dust concentrations of 1.38, 1.18, and 0.28 mg/m^3, respectively. Mixing of ingredients in a large vat had the highest mean dust concentration of 6.95 mg/m^3. The highest dust concentration of 34.14 mg/m^3 during the mixing of ingredients is shown on the graph.

Cinnamon smear

The overall mean dust concentration for the cinnamon smear tasks was 2.95 mg/m^3 for a 35-minute HazDust sample. Dumping of ingredients, mixing of ingredients in a large vat, scraping batter from vat sides and blades, opening containers, and moving the vat were evaluated. Dumping of ingredients had the highest mean dust concentration of 9.58 mg/m^3. Mixing of ingredients in a large vat, scraping batter from vat sides and blades, opening containers, and moving the vat had mean dust concentrations of 0.77, 0.64, 0.52, and 0.55 mg/m^3, respectively. The peak concentration for the cinnamon smear operation was 101.24 mg/m^3 occurring cinnamon was added to the mixer.

Caramel smear

The overall mean dust concentration for the caramel smear tasks was 0.38 mg/m^3 for an 11-minute HazDust sample. Various tasks were evaluated, including pouring the cream mixture, mixing of the ingredients, weighing the cream mixture, and closing the container lids. Pouring the cream had a mean dust concentration of 0.27 mg/m^3. Mixing and weighing of the cream had mean dust concentrations of 0.26 and 0.27 mg/m^3, respectively. The last task, closing the container lids, had the highest mean dust concentration of 1.58 mg/m^3 with a high peak of 5.33 mg/m^3.

Bench-top weighing

The overall mean dust concentration for the bench-top weighing task was 1.44 mg/m^3 for a three-minute HazDust sample. The highest dust concentration, 7.46 mg/m^3, occurred when the worker scooped dry ingredients from the storage bin.

Discussion

Previous studies indicated that workers who mix and weigh powder materials can have high exposures to dust [Gressel et al. 1987; NIOSH 2008a, b]. The bulk mixing task for baguettes was evaluated as part of this survey to assess potential exposure to dust and food related flavorings. Figure 3 shows the real time data where one peak exposure was noted during this task. This peak concentration was associated with the worker hitting the flour silo to encourage more flow into the mixer. Once the worker stopped hitting the silo, the dust concentration dropped down to background. This result illustrates the important influence of work practices on potential exposures.

The HazDust IV measured the highest dust levels of the field survey during the cinnamon smear task. While monitoring the cinnamon smear task, NIOSH researchers observed that the local exhaust ventilation (LEV) ducting on the mixer was not connected. Lack of LEV may have contributed to the area having visible airborne and settled cinnamon and powdered sugar dust. The cinnamon smear task was a concern because a butter and vanilla flavoring was used during the production process. Butter and vanilla flavorings frequently contain diacetyl as an ingredient. The peak exposure of 101.24 mg/m^3 occurred when cinnamon contained in a bucket was added to the mixer manually.

The caramel smear had the lowest dust concentrations of all the operations studied. There were no powders or flavorings used during this task. The cinnamon and caramel smear tasks were performed in the same work area; therefore, potential cross-contamination may explain the dust concentration reported by the HazDust IV during the caramel smear production process.

The bench-top weighing task had a similar dust concentration as the bulk mixing task. There were two peak exposures caused by the worker reaching into the storage bins to scoop dry ingredients. The dust concentration returned to background after the worker finished scooping the ingredients.

During the plant walk-through, the LEV at the cinnamon station was the only engineering control noted. The LEV was not connected during the time of the survey; therefore, a ventilation evaluation was not conducted.

Conclusions

NIOSH researchers conducted an engineering control survey at Baker Boy to evaluate the processes regarding potential exposure to diacetyl and other food related flavorings. Due to the potential exposure to diacetyl, workers whose tasks involved weighing and mixing ingredients and smear operations were targeted for evaluation. Diacetyl concentration at Baker Boy was non-detectable for the bulk mixing task evaluated during the engineering controls assessment survey. Real-time HazDust IV mean dust concentrations for all the evaluated tasks were below the respirable dust PEL of 5 mg/m^3. Mineral, inorganic, or organic dusts not specifically listed by substance name, are covered by the particulates not otherwise regulated (PNOR) PEL; however, the absence of specific regulation does not imply safety. The OSHA PEL for PNOR applies to particulates with low toxicity and is not designed to protect workers from bronchiolitis obliterans or other chronic obstructive respiratory disorders.

Recommendations

Since there is some uncertainty of actual dust exposure using the real-time instrument, several recommendations are provided to reduce dust exposure and further control flavoring exposures, including exposure to diacetyl.

General Recommendations

1. Reduction of exposure through engineering controls such as LEV and work practices aimed at reducing dust and chemical vapor generation are primary preventive steps.

2. Clean spills immediately. Shovel large spills carefully into a waste bag. Workers might need to wear respiratory protection when cleaning spills. Employers who allow their employees to wear respirators on a voluntary basis when not required by OSHA or the employer must implement limited provisions of a respiratory protection program. When a filtering face piece respirator is all that is used, the employee must be provided a copy of Appendix D [29 CFR 1910.134 Appendix D]. For all other voluntary users, an additional written respirator program that covers medical fitness and proper maintenance procedures must be implemented.

3. Do not clean a dry spill with a brush or with compressed air. Vacuum or wet cleaning (when it does not present another safety hazard, i.e., electrical or slip hazards) processes are recommended.

4. Enclose the mixer (i.e., ventilated booth) as much as possible and, if possible, provide seals on the lids and other access points to control any potential fugitive emissions.

5. Where possible, locate the working area away from doors, windows, and walkways to prevent drafts from interfering with the ventilation and the spreading of dusts.

Task-specific Recommendations

1. Since weighing and pouring are often performed on a bench-top workstation, the addition of a ventilated booth for both the bench and the weighing area is recommended to control dust and chemical exposure. The British Health and Safety Executive (HSE) has developed a series of control approaches based on common processes in a variety of industries (see Figure 5) [Health and Safety Executive 2003]. Another design is the ventilated backdraft

workstation adapted from welding bench designs available in the ACGIH® *Industrial Ventilation Design Manual* [ACGIH 2010]. It has been evaluated by NIOSH in two flavoring production plants [NIOSH 2008a; NIOSH 2008b]. These stations were designed to maintain an air velocity of 100–150 feet per minute (fpm) at the face of the enclosure. The field studies showed reductions in exposure of 90%–97% when performing mixing tasks using these stations [NIOSH 2008a]. The key design parameters are to enclose as much of the activity as possible and to use properly sized exhaust slots to maintain a uniform air velocity across the face of the station.

2. Bag dumping and disposal during the cinnamon smear task created a significant amount of dust. Bag opening, dumping, and disposal of empty bags needs to be done in a ventilated enclosure [Heitbrink and McKinnery 1986]. A ventilated bag dump station, consisting of a hopper outfitted with an exhaust ventilation system to pull dusts away from workers as they open, dump, and discard bags of powdered material, is frequently used in bag dumping operations and should be considered for this facility. The designs for these devices are available from several sources of good industrial ventilation guidance. HSE has developed a control approach for a ventilated station for emptying bags of solid materials. The control includes the specification of a face velocity of 200 fpm (1.0 m/s) and includes a waste bag collection chute (see Figure 6) [Health and Safety Executive 2003]. The ACGIH® *Industrial Ventilation Design Manual* also has two designs that are applicable to the control of powder materials during bag dumping. Design plate VS-15-20, Toxic Material Bag Opening, is similar in design to the HSE station described above but recommends a slightly higher control velocity of 250 fpm at the face of the station opening. In addition, design plate VS-50-10, Bin and Hopper Ventilation, requires a hood face velocity of 150 fpm. Air velocities around 150 fpm into the hood should provide reasonable contaminant removal for these operations at Baker Boy [ACGIH 2010].

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Appendix

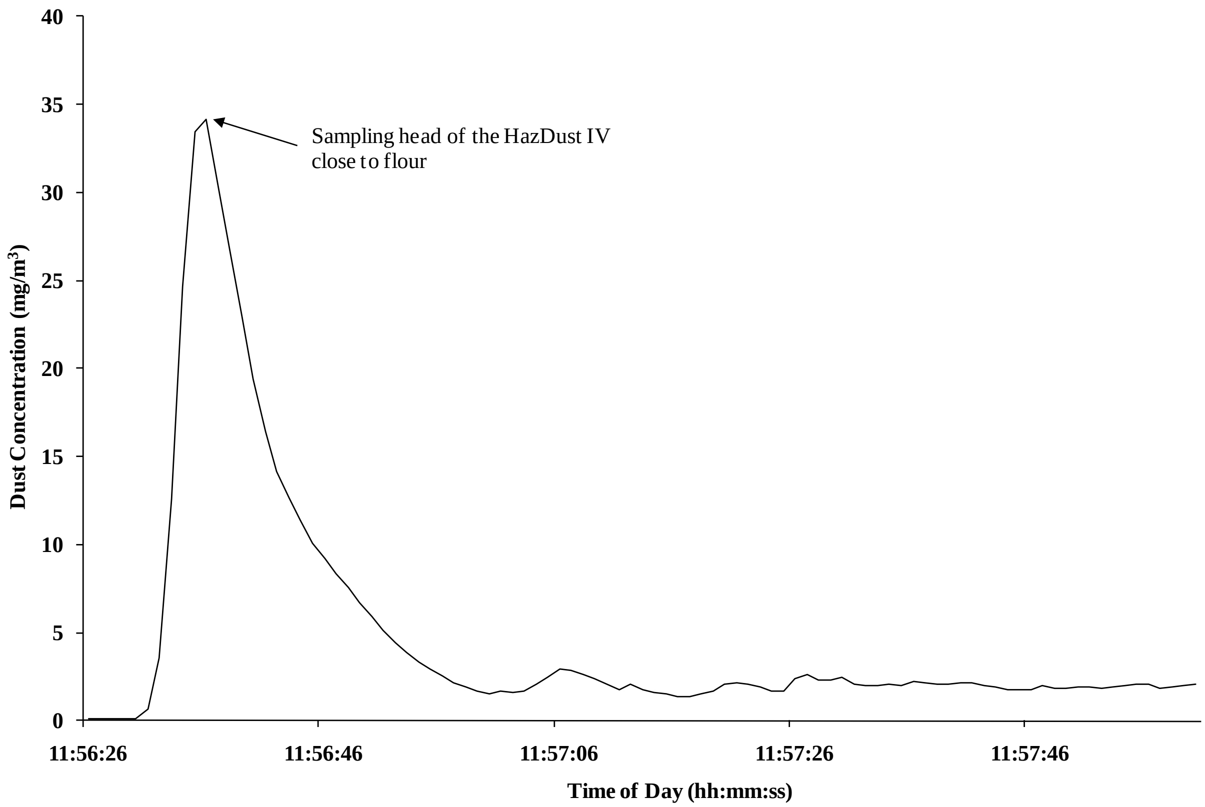

Figure 1. Real-time Data for Bulk Mixing

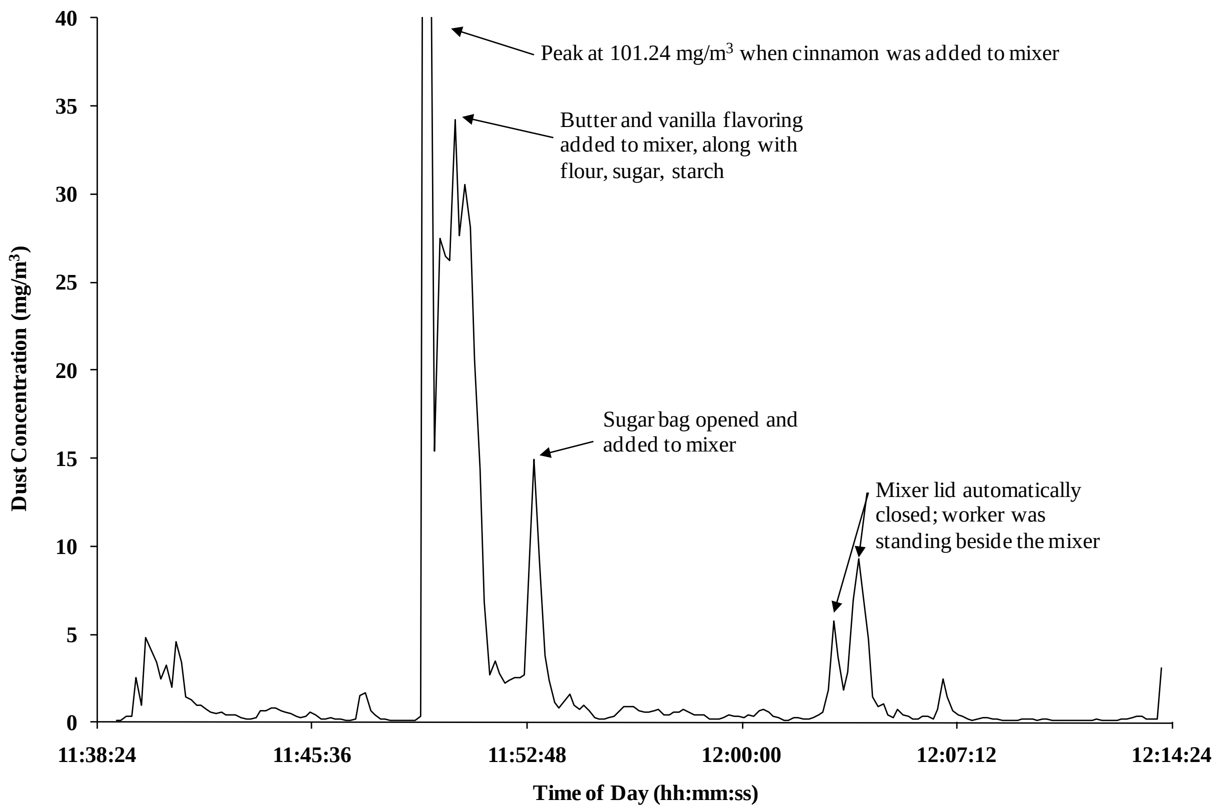

Figure 2. Real-time Data for Cinnamon Smear Dust

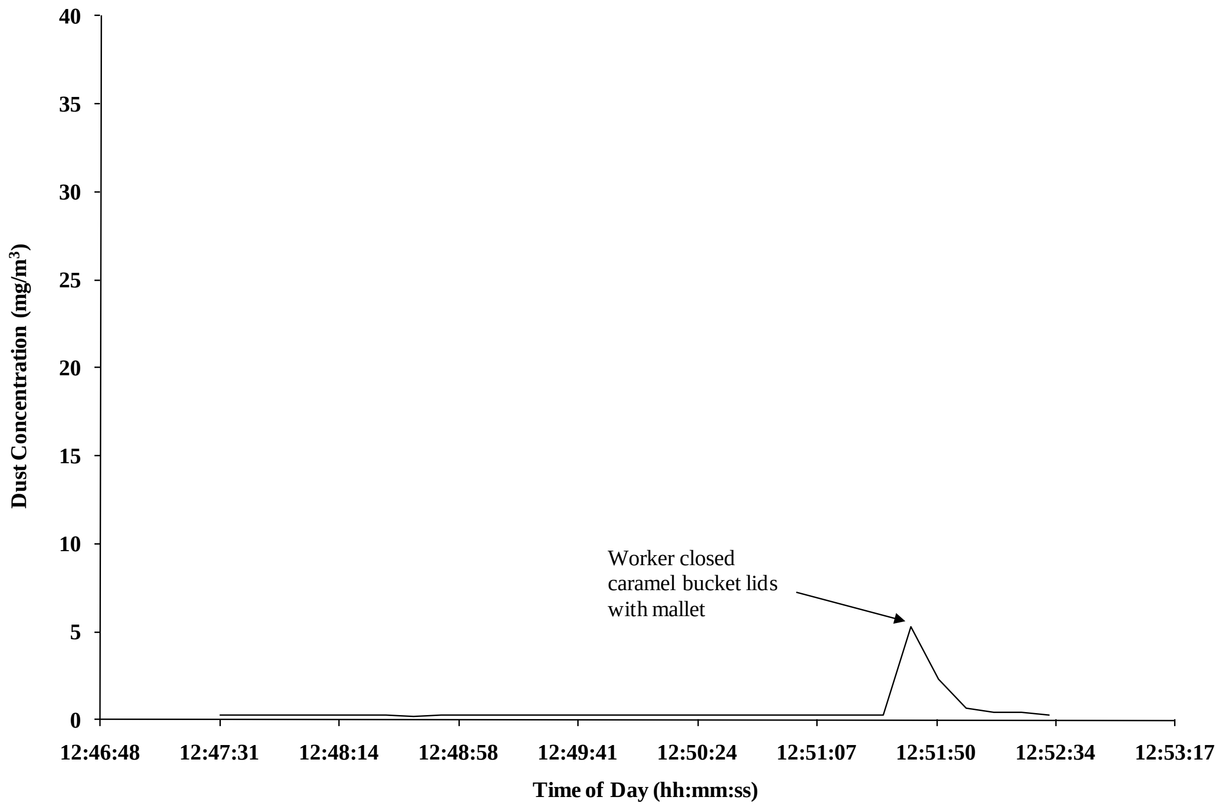

Figure 3. Real-time Data for Caramel Smear

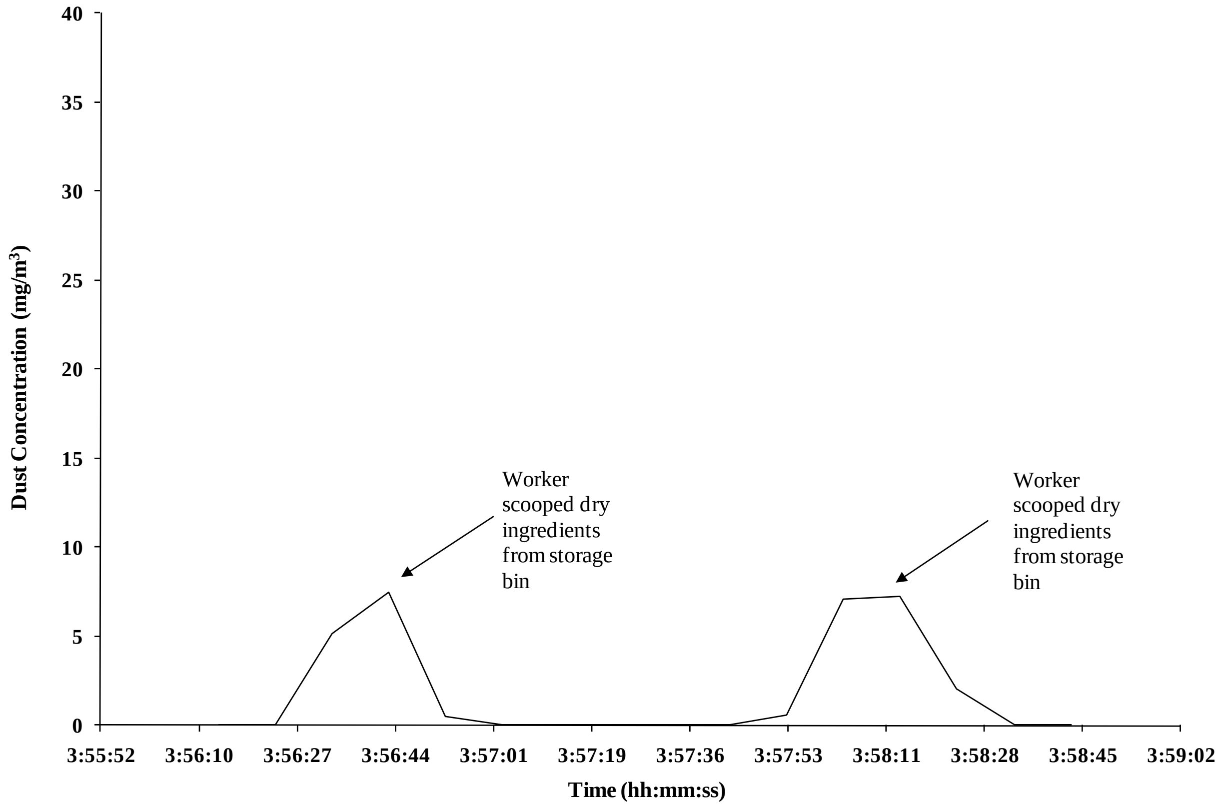

Figure 4. Real-time Data for Benchtop Weighing

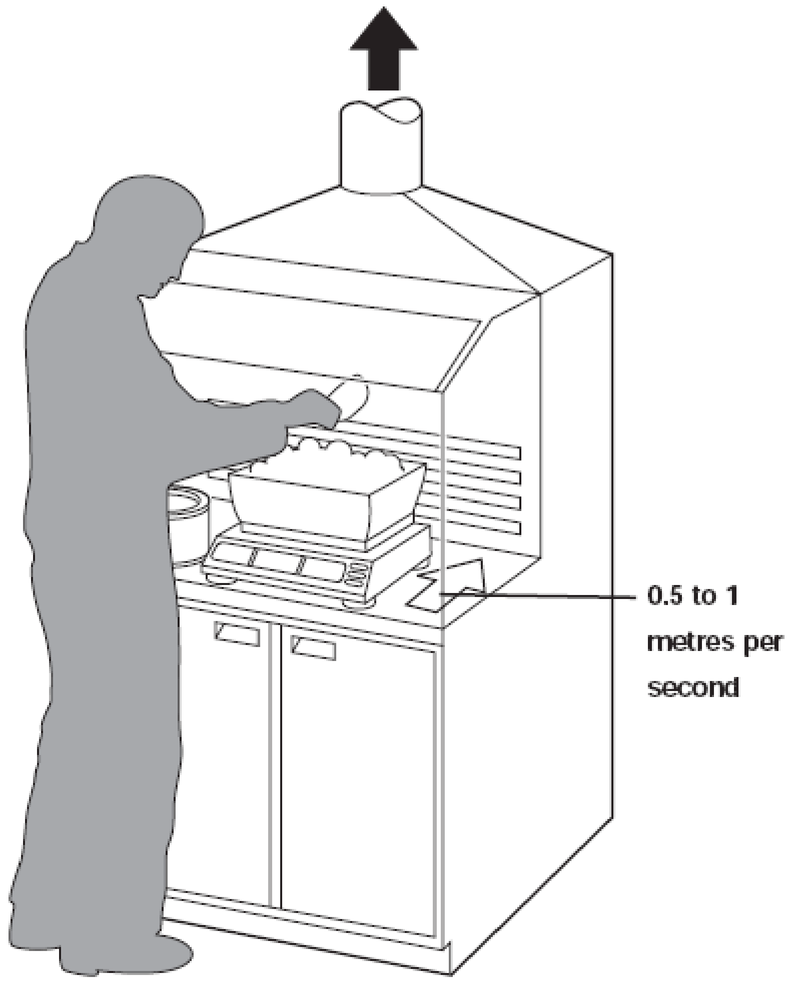

Figure 5. Bench-top ventilation for weighing/handling powders (HSE FL02) (0.5-1 m/s is equivalent to 100-200 fpm). Contains public sector information published by the Health and Safety Executive and licensed under the Open Government Licence v1.0.

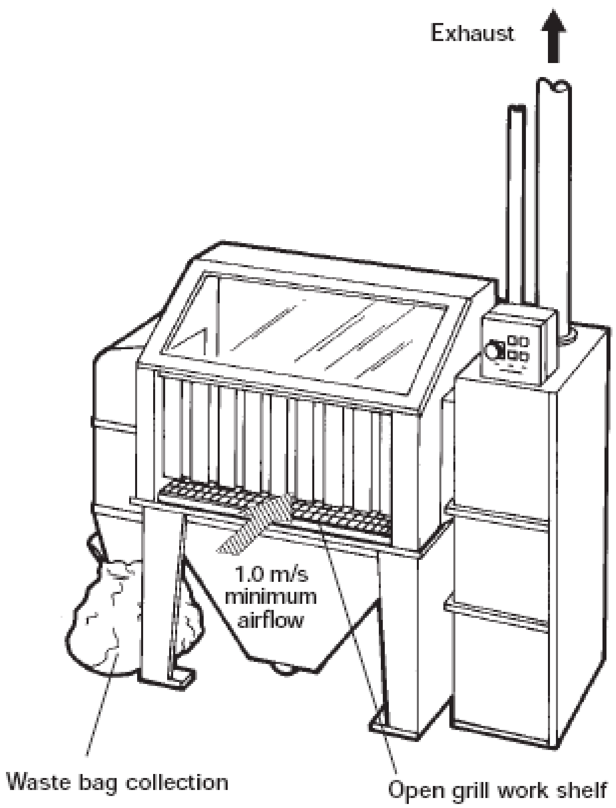

Figure 6. Ventilated Bag Dumping/Emptying Station, 1.0 mps is equivalent to 200 fpm. Contains public sector information published by the Health and Safety Executive and licensed under the Open Government Licence v1.0.

Table 1. Job Category and Corresponding Peak and Mean HazDust Dust Concentration Measurements

Job Category	Task	Peak Concentration (mg/m^3)	Mean Concentration (mg/m^3)
Bulk Mixer		34.14	1.38
	Dumping ingredients		1.38
	Mixing ingredients		6.95
	Bench-top weighing		1.18
	Moving vat		0.28
Cinnamon Smear Operator		101.24	2.95
	Dumping of ingredients		9.58
	Mixing of ingredients in a large vat		0.77
	Scraping batter from vat sides and blades		0.64

Job Category	Task	Peak Concentration (mg/m³)	Mean Concentration (mg/m³)
	Opening containers		0.52
	Moving vat		0.55
Caramel Smear Operator		5.33	0.38
	Pouring mixture		0.27
	Mixing ingredients		0.26
	Weighing mixture		0.27
	Closing lids		1.58
Bench-top Weighing Operator		7.46	1.44
	Scooping dry ingredients		1.44

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