In-Depth Survey Report

Engineering Control and Process Evaluation at Quaker Oats

Alberto Garcia, M.S.

Deborah V.L. Hirst, Ph.D., E.I.

Brian D. Curwin, Ph.D.

Division of Applied Research and Technology
Engineering and Physical Hazards Branch
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Surveys Conducted By: Alberto Garcia, M.S., NIOSH

Brian D. Curwin, Ph.D., NIOSH

James R. Couch, M.S., NIOSH

Kevin L. Dunn, NIOSH

Karl Feldmann, NIOSH

Employer Representatives
Contacted: Kori Shane

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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 Cedar Rapids, Iowa Quaker Oats, a producer of cereal and other grain mill products, 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; these results are included in a separate report. Personal sampling (from the exposure assessment study) and a ventilation assessment were conducted to evaluate potential risks during various tasks monitored during the engineering control survey.

In general, measured diacetyl concentrations at the Cedar Rapids, Iowa, Quaker Oats facility were below the proposed NIOSH Recommended Exposure Limit (REL), with the exception of the Syrup room on the 5th floor. Samples collected in this room had levels of diacetyl above the proposed NIOSH time weighted average (TWA) of 5 parts per billion (ppb) and Short Term Exposure Limit (STEL) of 25 ppb. This room also had concentrations of 2,3-pentanedione above the proposed NIOSH REL for 2,3–pentanedione of 9.3 ppb.

Real-time HazDust IV mean dust concentrations for all the evaluated tasks were below the respirable dust 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 regarding 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. Reduction of 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 compressed air. Vacuuming or wet cleaning processes are recommended.

4. Enclose the mixer as much as possible and, if possible, provide seals on the lids and other access points.

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

Task-specific Recommendations

1. The use of ventilation at the drum opening has been recommended for capture of vapors during transfer of chemicals. For drum filling, the use of an annular exhaust hood around the interface between the drum and feed pipe (at the bung hole) is recommended. The recommended airflow is a minimum of 100 feet per minute (fpm) across the drum cap/bung hole. For flammable liquids, suitable fans and equipment as well as appropriate grounding schemes should be used to prevent the buildup and discharge of static electricity.

2. Since weighing and pouring are often performed on a bench-top workstation, the addition of a ventilated booth for both the bench/weighing area is recommended to control dust and vapor exposure.

3. Bag dumping and disposal during the tumbler filling operation can potentially create a significant amount of dust. Bag opening, dumping, and disposal of empty bags should occur in a ventilated enclosure. A ventilated bag dumping station, consisting of a hopper outfitted with an exhaust ventilation system is frequently used in bag dumping operations and should be considered for this facility.

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

On August 17th – 21st, 2009, NIOSH researchers visited the Quaker Oats facility in Cedar Rapids, Iowa, to conduct an engineering control and exposure assessment survey for diacetyl and related flavoring compounds. This report presents the results of the engineering control assessment conducted during the site visit. The detailed results from the exposure assessment survey are included in a separate report. NIOSH is engaged in occupational health and safety research on diacetyl and other food flavoring chemicals.

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 1994]. 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. Diacetyl is commonly used in the flavor manufacturing industry in the production of various 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 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.

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

The Quaker Oats Co. based in Chicago, Illinois, is a private company categorized by NAICS code under Cereal Breakfast Foods. Current estimates for the Cedar Rapids, Iowa, facility show this location employs a staff of approximately 900. The facility manufactures cereal, flour and other grain mill products, prepared pancake mixes, and flavor extracts.

Description of Processes and Controls

Four areas of the plant were evaluated during the engineering control assessment. These areas were selected because flavoring chemicals are handled on a routine basis and also because some type of engineering control was installed to limit exposures to flavoring chemicals.

The four areas selected include:

1. The syrup room on the 5th floor
2. The tumblers on the 6th floor
3. The barrel coaters on the 9th floor
4. The mixer station on the 12th floor

The syrup room is a storage/containment room located on the 5th floor where multiple 55-gallon drums are kept. This room was located toward one end of the building, and is a rectangular room where one wall is an exterior wall. The drums inside the room were closed except those four where liquids were actively being pumped. From this room, liquid flavorings are automatically pumped to each of the processes throughout the facility in exact automated quantities. Monitors indicate levels inside of each drum, and potential exposure to flavoring chemicals occurs when a worker enters the room to switch the drum/vat pumps from one drum to another. This process is typically completed within 5 minutes. At the time of the evaluation, workers were required to wear goggles, hearing protection, and hairnets to complete this operation.

Multiple tumblers are located on the 6th floor. Tumbler mixers operate by tumbling the mass of solids inside a revolving vessel. Typically cubes, drums, double-cones and V-shapes are used for the vessel. Tumblers were used to mix powder flavorings, generally flour, dextrose and specific quantities of pre-mixed powder flavorings. A platform is used to load the tumblers with the powders required to create a given formulation. Workers load the tumblers manually with the ingredients required to achieve the desired product. Once the tumblers are loaded, a forklift moves the assembly to an area where tumblers are automatically agitated to promote mixing and achieve a homogeneous product. Once the agitation process is completed, the tumblers are moved to a separate area where they are coupled with discharge hoses to dump the mix directly into the desired process. At the time of the evaluation, workers were required to wear goggles, hearing protection, and hairnets to complete this process.

Barrel coaters are typically used as single stage coating equipment. Usually, the flavoring is applied as a dry seasoning, or seasoning blend. The barrel coater consists of a large inclined cylinder that rotates to lift the product. The drum inner walls include product lifting flights to create the desired coating. Product is picked up by the flights near the bottom of the drum and lifted as the drum rotates. Once the product reaches a critical height, it begins to turn or roll down to the bottom of the drum where the lifting process begins again. The product is transported forward because the drum is inclined downward from entrance to exit. Each time the product completes a cycle of lifting and falling, it moves closer to the discharge end of the drum [Lusas 2001]. The dry seasonings are usually brought into the coating drum using an auger feeder. The flights of the coater are filled in the supply hopper as the auger rotates, and an equal amount of seasoning is deposited into the coating drum. The finished products are then moved by conveyor belts to the packaging stage of the production process. The upper section of the barrel was equipped with a small hood connected by a flexible duct to a main duct. This is a continuous process and mostly automated with little worker interaction. Occasionally, a worker verifies proper operation of the barrel coater by standing on a platform and observing the coating process. At the time of the evaluation, workers were required to wear goggles, hearing protection, and hairnets to complete this operation.

The mixer station located on the 12th floor consisted of a small size ribbon blender where powder products and small quantities of liquid flavorings were dumped to create a desired mix. Workers manually loaded the blender with powders and liquids in the required quantities to meet the formulation. The ribbon blender was equipped with lids to enclose the blender once the products were added, but no LEV was provided at the time of the visit. Then products were directly routed to the lower stories of the building to feed one of the many different manufacturing processes at Quaker Oats Co. At the time of the evaluation, workers were required to wear goggles, hearing protection, and hairnets to complete this operation.

Occupational Exposure Limits

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 Threshold Limit Value (TLVs®) recommended by the American Conference of Governmental Industrial Hygienists (ACGIH®), a professional organization [ACGIH 2010a]. 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.

Exposure Criteria

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.

Exposure to diacetyl can occur by inhalation or skin contact [OSHA 2008]. Although listed as a high priority chemical by FEMA, there is no OSHA PEL or NIOSH REL for diacetyl [Martyny et al. 2008]. NIOSH has proposed a 10-hr time weighted average (TWA) and Short Term Exposure Limit (STEL) REL of 5 ppb and 25 ppb respectively [NIOSH 2011]. Table 5 summarizes most OEL's for a variety of chemicals normally used in the food flavoring production industry.

Methodology

Exposure Assessment

Full shift area and personal air samples were collected in selected production areas for the following compounds: ketones (diacetyl, acetoin, 2,3 pentanedione, 2,3 hexanedione, 2,3 heptanedione), acids (butyric, acetic and propionic), aldehydes (2-furaldehyde, acetaldehyde, benzaldehyde, isovaleraldehyde, and propionaldehyde), and respirable dust. Additionally, an air sample for a VOC screening was also collected with the area samples. Bulk samples were collected from various seasoning powders and liquids. The sampling methods used and the limits of detection (LOD) are provided in Table 1. The dates and locations where the air sampling occurred are presented in Tables 2 and 3. The tasks sampled included weighing, mixing, and pouring during various cereal production processes.

The air samples for diacetyl, acetoin, 2,3-pentanedione, 2,3-hexanedione, 2,3-heptanedione were analyzed with the OSHA Diacetyl and Acetoin Method 1013 [OSHA 2008]. Method 1013 requires that air samples be collected by drawing air through two sampling tubes containing dried and cleaned silica gel, connected in series. 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) using a standard flow meter (Bios DryCal DC-LITE, Model DCLM REV. 1.08, BIOS, Butler, NJ).

Samples for respirable dust were collected and analyzed using NIOSH Method 0600. Method 0600 requires air to be drawn through a cyclone and a 37 mm PVC filter. SKC Pocket Pumps were calibrated and set at a nominal flow rate of 1.5 L/min for Method 0600 using a standard flow meter (Bios DryCal DC-LITE).

Sample results from OSHA Method 1013 were reported in micrograms (µg) of analyte per sample. Analytical results were converted to an airborne concentration using Equations 1 and 2. The LOD 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:

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

Where,

C_{ppm} = concentration, ppm

MW = molecular weight [Lide 2008]

Local Exhaust Ventilation (LEV) Characterization

A variety of methods were used to evaluate the LEV system. Initial characterization included measuring exhaust flow rates, face velocities, and slot velocities for each LEV hood. The capture velocity of the hood is defined as the velocity created by the hood at the point of contaminant generation (Goodfellow and Tahti, 2001). For enclosing hoods, the capture velocity is the air velocity measured at the face of the hood. To provide uniform velocity across the face of a hood, exhaust slots are typically used. In addition to the face and slot velocity measurements, a smoke tracer is used to confirm the direction of the airflow and effect of secondary airflows on hood performance. Secondary airflows can be attributed to natural plant draft currents, auxiliary fans to aid with cooling, or simply the effect of moving objects in the proximity of the hoods.

Hood Velocity Measurements

Equipment

A TSI VelociCalc Plus Model 8388 thermal anemometer (TSI Incorporated, St. Paul, MN) was used to measure air speeds at the face of each hood.

Procedure

Face velocity tests were performed by dividing the opening of the hood into equal area grids of approximately 0.09 m^2 (1 ft^2) calculating the mean of 5-

second average velocity measurements at the center point of each grid. Each measurement was made with the anemometer probe held perpendicular to the air flow direction at each center point. Air velocities were also measured across each slot hood to evaluate the air flow distribution across these LEV hoods. Slot velocities were logged approximately every 0.25 meters (10 inches) across the length of the slot.

Hood Qualitative Smoke Tracer Test

Equipment
A Wizard Stick (Zero Toys, Inc., Concord, MA) smoke generator was used to visualize air movement inside and around the periphery of the hood.

Procedure
Smoke was released around the periphery of each LEV hood and in the interior of each enclosing hood to qualitatively evaluate the capture efficiency and determine areas of concern. If the smoke was captured quickly and directly by the hood, it was a good indication of acceptable control design and performance. If the smoke was slow to be captured when released at a certain point, or took a circuitous route to the air intake for the exhaust, the hood design was considered marginal at that point. Smoke release observations were made in the interior of the enclosing hoods to look for reverse flow and at the edges of the hood to identify escape. Also, the adverse effect of cross drafts on the hood was evaluated by releasing smoke near the periphery of the hood face.

Real Time Exposure Monitoring Tests

Dust
Equipment
A HazDust IV hand-held aerosol photometer (Environmental Devices Corporation, Plaistow, NH) measured dust concentration. It operates on the principle of near-forward light scattering. It provides real-time measures of airborne dust particle concentration 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. The HazDust IV can detect particle sizes from 0.1 to 100 micrometers (µm) and dust concentrations from 0.01 to 200 mg/m^3, respectively. The HazDust IV is calibrated with the NIOSH gravimetric reference-NIST traceable–SAE fine test dust; it does not differentiate between types of dust and may respond differently to dusts with optical properties different from fine test dust. As this may cause some uncertainties in the actual dust concentrations, reported concentrations should be taken as a relative measure.

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 various operations (mixing, coating, and syrup manufacturing) to measure dust concentrations. The sampling head of the HazDust IV was positioned near the worker's breathing zone. The HazDust IV recorded data in ten-second intervals. Data from the instrument were downloaded to a computer and analyzed using Microsoft Excel.

Volatile Organic Compounds (VOC)

Equipment

A MiniRAE 2000 (RAE Systems Inc., San Jose, CA) photo-ionization detector (PID) was used to measure volatile organic compound concentrations in parallel with the HazDust IV. The PID is calibrated using isobutylene, and it does not differentiate between types of VOC's and may respond differently to vapors with optical properties different from isobutylene. As this may cause some uncertainties in the actual VOC concentrations, reported concentrations should be taken as a relative measure.

Procedure

The PID was placed on the worker (using a fishing vest) near his/her breathing zone to evaluate engineering control effectiveness while performing activities in the barrel coaters, mixing stations, tumblers, and syrup manufacturing. The instrument was set to log a data point every second for the duration of the task.

Results

A total of 21 area samples and 9 personal samples were collected and analyzed using OSHA Method 1013. The results for the area air samples are presented in Table 2, and the results of the personal air samples are presented in Table 3. Diacetyl was detected in three of 17 area samples, but in none of the personal air samples. The positive samples were all in the syrup room. Three out of 11 bulk samples collected from various flavorings had detectable levels of diacetyl (Table 4). Those flavorings were natural butter, butter berry, and vanilla ice cream flavors. Natural butter flavor also contained acetoin and 2,3-pentanedione. Several other flavorings also showed traces of acetoin and 2,3 heptanedione. 2,3-pentanedione and 2,3-heptanedione are chemically similar to diacetyl.

HazDust IV Results

HazDust IV concentrations were measured in 3 different production areas: 1) the tumblers on the 6th floor, 2) the barrel coaters on the 9th floor, and 3) the mixer station on the 12th floor. The overall mean dust concentration for workers loading the tumblers was 1.75 mg/m^3, 0.84 mg/m^3 for the operator of the barrel coater, and non-detected (ND) for the worker on the mixer station. The syrup room was not evaluated with the HazDust IV as powdered chemicals or flavorings were not handled in the area. The HazDust IV real-time data results are reported as relative concentrations to Arizona Road Dust. Figure 1 shows the real time data collected with the HazDust IV in the three sampled locations.

PID Results

Figure 2 shows the real time VOC measurements collected using the PID in the four areas of interest. The overall mean concentration was 9.58 ppm for the syrup area, 0.35 ppm for tumbler area, 0.16 ppm for the barrel coaters, and 0.18 ppm for the mixer station. The PID results show a high VOC concentration in the syrup room. As the PID is not calibrated specifically for diacetyl, it is hard to say whether VOC concentrations were attributed solely to diacetyl or due to a mix of other organic vapors. Results from the integrated samples reported earlier indicate that there were concentrations of diacetyl above the proposed NIOSH REL of 5 ppb in the syrup room.

LEV Measurements

LEV measurements were collected in two LEV hoods in the facility. There was a small slotted hood located behind a weigh-in station in the tumbler area on the 6^{th} floor. Measurements were also collected at the upper section of the barrel coater on the 9^{th} floor which was equipped with a small hood connected by a flexible duct to a main duct.

The slot hood in the tumbler area was equipped with adjustable slot openings for ease of balancing. At the time of the visit, the slot openings were found to be completely opened resulting in a reduced air velocity into the hood. Average face velocity of the slotted hood was measured at 51 fpm into the hood with a volumetric flow rate of 42 cfm. There were calibration marks on the side of the hood which might have been added by the contractor who installed the LEV system. The slot opening width was then reduced from 3 inches to 0.75 inch to increase air velocity. Measurements were collected for a second time once the openings were adjusted and the average air velocity increased to 246 fpm with a volumetric flow rate of 49 cfm. This hood was located approximately 3 inches from the weighing station. Smoke tests on the slot hood initially showed no visible movement in front of the hood. Once adjusted, smoke flowed directly into the hood.

Measurements collected from the hood located on the upper section of the barrel coater showed an average face velocity of 451 fpm and a calculated flow rate of 295 cfm. Smoke tests on the hood located on the barrel coater showed good capture.

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]. Currently, there is no model or standard guidance for engineering controls for flavoring and food production processes. If it is not possible to eliminate toxic compounds from the workplace or replace them with less toxic substances, then the use of engineering controls and work practices to minimize exposures is necessary.

Concentrations in the syrup room exceeded the proposed draft REL for diacetyl of 5 ppb. Diacetyl concentrations in this space are attributable to vapors originating from the open containers. The barrels were equipped with automatic pumps to minimize worker interaction with flavoring chemicals. These pumps are designed to dispense controlled quantities of liquid flavorings to different production processes around the facility. Worker interaction only occurred when a drum has been emptied and the pump needs to be moved to another drum. Although the use of these devices can reduce exposure by reducing the amount of open handling, care must be taken when filling and emptying drums of flavoring ingredients. The use of ventilation at the barrel opening has been recommended for capture of vapors during transfer of chemicals. Because the room is located adjacent to an exterior wall, vapors collected from the ventilated pumps could easily be directly discharged to the exterior.

Conclusions

In general, measured diacetyl concentrations at the Cedar Rapids, Iowa, Quaker Oats facility were below the proposed NIOSH REL, with the exception of the syrup room on the 5^{th} floor. Samples collected in this room showed levels of diacetyl above the proposed NIOSH TWA and STEL REL of 5 ppb and 25 ppb, respectively. This room also had levels of 2,3-pentanedione above the proposed NIOSH REL of 9.3 ppb.

There was a small amount of exposure to respirable particulates. However, all samples were below the OSHA PEL. Since diacetyl was found in some of the bulk samples collected by the exposure assessment team, it can be assumed that diacetyl was present in some of the respirable particulate samples. Some bulk powder samples contained 2,3-heptanedione, and it may, therefore also be present in the respirable particulate samples. Consequently, respirable dust exposures are of concern. Currently, there is not an analytical method for determining the concentration of diacetyl in particulate matter suspended in the air. A qualitative assumption of the presence of these chemicals in the respirable particulates can be made based on the presence of these chemicals in bulk samples.

Recommendations

Several recommendations are provided to reduce dust and potential diacetyl exposure, and further control flavoring exposures.

General Recommendations

1. Reduction of exposure through engineering controls such as LEV and work practices aimed at reducing dust and chemical vapor generation should be encouraged as a primary preventive step.

2. Clean spills immediately. Shovel large spills carefully into a waste bag. Workers might need to wear respiratory protection when cleaning spills. 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 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. The use of ventilation at the barrel opening has been recommended for capture of vapors during transfer of chemicals. The British Health and Safety Executive (HSE) has developed two engineering control approaches for drum filling and emptying (see Figure 3) [Health and Safety Executive 2003a, b]. For drum filling, the guidance recommends the use of an annular exhaust hood around the interface between the drum and feed pipe (at the bung hole). The recommended airflow is a minimum of 100 feet per minute (fpm) across the drum cap/bung hole. For flammable liquids, suitable fans and equipment as well as appropriate grounding schemes should be used to prevent the buildup and discharge of static electricity. The *ACGIH® Industrial Ventilation Design Manual* has a design plate with several different implementation options based on the process (see Figure 4) [ACGIH 2010]. In all cases, when transferring flammable

liquids, grounding and bonding requirements must be met to prevent sparks and explosions [National Fire Protection Association 2007].

2. Since weighing and pouring are often performed on a bench-top workstation, the addition of a ventilated booth for both the bench/weighing area is recommended to control dust and vapor exposure. HSE has developed a series of control approaches based on common processes in a variety of industries (see Figure 5) [Health and Safety Executive 2003c]. Another design is the ventilated backdraft workstation adapted from welding bench designs available in the ACGIH® *Industrial Ventilation Design Manual* (see Figure 6) [ACGIH 2010b]. 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 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.

3. Bag dumping and disposal during the tumbler filling operation can potentially create a significant amount of dust. Bag opening, dumping, and disposal of empty bags should 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 industrial ventilation guidance. HSE has developed an approach for a ventilated station for emptying bags of solid materials that includes a specified face velocity of 1.0 m/s (200 fpm) and a waste bag collection chute (see Figure 7) [Health and Safety Executive 2003d]. The ACGIH® *Industrial Ventilation Design Manual* includes 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 face velocity of 1.27 m/s (250 fpm). In addition, design plate VS-50-10, Bin and Hopper Ventilation, requires a hood face velocity of 0.76 m/s (150 fpm). Air velocities around 0.76 m/s (150 fpm) into the hood should provide reasonable contaminant removal for these operations [ACGIH 2010].

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References

ACGIH [2010a]. 2010 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [2010b]. Industrial ventilation: a manual of recommended practice for design. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [2007]. Industrial ventilation: a manual of recommended practice for operation and maintenance. Cincinnati, OH: ACGIH.

AIHA [2007]. 2007 Emergency Response Planning Guidelines (ERPG) & Workplace Environmental Exposure Levels (WEEL) Handbook. Fairfax, VA: American Industrial Hygiene Association.

Akpinar-Elci M, Travis WD, Lynch DA, Kreiss K [2004]. Bronchiolitis obliterans syndrome in popcorn production plant workers. Eur Respir J *24*(2):298–302.

California Code of Regulations [2009]. Title 8, §5197.

CFR [2003]. 29 CFR 1910.134. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

CFR [2003]. 29 CFR 1910.1000. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Environmental Devices Corporation [2010]. HD-1004 Brochure.

FEMA [2004]. Respiratory Health and Safety in the Flavor Manufacturing Workplace. [cited 2007 October 15]. Available from URL: http://www.femaflavor.org/html/public/RespiratoryRpt.pdf.

Goodfellow H. and Tahti E.[2001]. *Industrial Ventilation Design Guidebook*. Academic Press, London, UK.

Gressel, M., W. A. Heitbrink, J. D. McGlothlin, T. J. Fischbach [1987]. "Real-time, integrated, and ergonomic analysis of dust exposure during manual materials handling." Appl Ind Hyg **2**(3): 108-113.

Health and Safety Executive [2003a]. Drum emptying using a drum pump. In: COSHH essentials: easy steps to control chemicals. London: Health and Safety Executive.

Health and Safety Executive [2003b]. Drum filling. In: COSHH essentials: easy steps to control chemicals. London: Health and Safety Executive.

Health and Safety Executive [2003c]. Sack emptying. London, Health and Safety Executive.

Health and Safety Executive [2003d]. Weighing and handling flour improvers etc (craft bakery). London, Health and Safety Executive.

Heitbrink, W. A. and W. N. McKinnery Jr [1986]. "Dust control during bag opening, emptying and disposal." Appl Ind Hyg **1**(2): 101-109.

Kanwal, R., G. Kullman, C. Piacitelli, R. Boylstein, N. Sahakian, S. Martin, et al. [2006]. "Evaluation of flavorings-related lung disease risk at six microwave popcorn plants." J Occup Environ Med **48**(2): 149–57.

Kanwal, R. and S. Martin [2003]. Letter of May 13, 2003, from R. Kanwal and S. Martin, Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Department of Health and Human Services, to Keith Heuermann, B.K. Heuermann Popcorn, Inc. Phillips, NE.

Kreiss, K. [2007]. "Flavoring-related bronchiolitis obliterans." Curr Opin Allergy Clin Immunol **7**(2): 162–7.

Lide D, ed. [2008]. CRC handbook of chemistry and physics. Boca Raton, FL: CRC Press.

Lusas E.W., Rooney L.W.[2001]. Snack foods processing. CRC Press 518-519, Boca Raton, FL.

Martyny, J. W., M. V. Van Dyke, S. Arbuckle, M. Towle, C. S. Rose [2008]. "Diacetyl exposures in the flavor manufacturing industry." J Occup Environ Hyg **5**(11): 679–88.

National Toxicology Program [1994]. 2,3-Butanedione. CAS Number 431-03-8. [cited 5 May 2011]. Available from URL: http://ntp.niehs.nih.gov/ntp/htdocs/Chem_Background/ExSumPdf/431-03-8.pdf.

NIOSH [2011]. Draft Criteria for a recommended standard: occupational exposure to diacetyl and 2,3-pentanedione. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) (forthcoming).

NIOSH [1985]. Hazard evaluation and technical assistance report: International Baker Services, Inc, South Bend, IN. R. By McConnell and R. Hartle. Cincinnati, OH, U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health. NIOSH HETA Report No. 1985–0171–1710.

NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

NIOSH [2003]. NIOSH alert: preventing lung disease in workers who use or make flavorings. Cincinnati, OH, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 2004–110: 15.

NIOSH [2008a]. In-depth survey report: evaluation of engineering controls for the mixing of flavoring chemicals at Gold Coast Ingredients, Inc. Commerce, CA. Cincinnati, OH: . U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Survey Report No. EPHB 322–11a.

NIOSH [2008b]: In-depth survey report: evaluation of engineering controls for the production of liquid and powder flavoring chemicals at Kerry Ingredients and Flavours, Inc. formerly Mastertaste, Inc., Commerce, California. DHHS (NIOSH) Publication No. EPHB 322-12a.

OSHA [2008]. Acetoin and Diacetyl. [cited 2010 January 14]. Available from URL: http://www.osha.gov/dts/sltc/methods/validated/1013/1013.html.

Parmet, A. J. and S. Von Essen [2002]. "Rapidly progressive, fixed airway obstructive disease in popcorn workers: a new occupational pulmonary illness?" J Occup Environ Med **44**(3): 216–8.

van Rooy, F. G., J. M. Rooyackers, M. Prokop, R. Houba, L. A. M. Smit, D. J. J. Heederik [2007]. "Bronchiolitis obliterans syndrome in chemical workers producing diacetyl for food flavorings." Am J Respir Crit Care Med **176**(5): 498–504.

Appendix

Figure 1. Real Time for HazDust IV Data

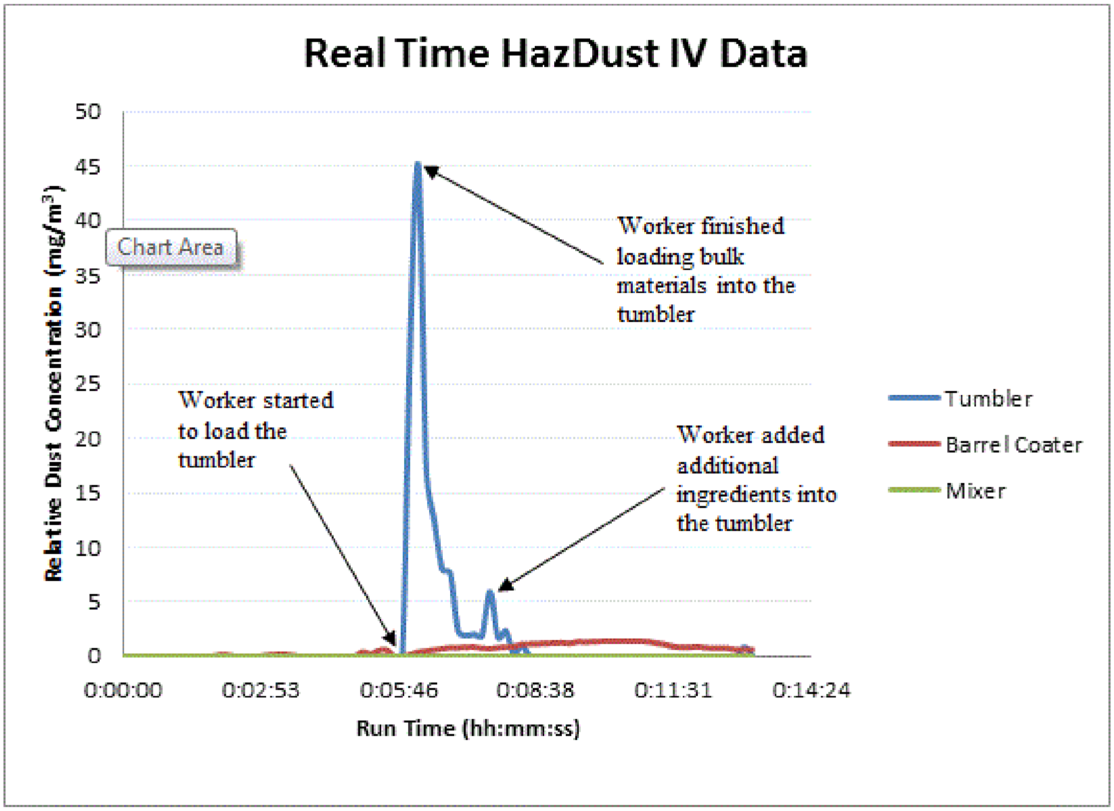


Figure 2. Real Time PID Data

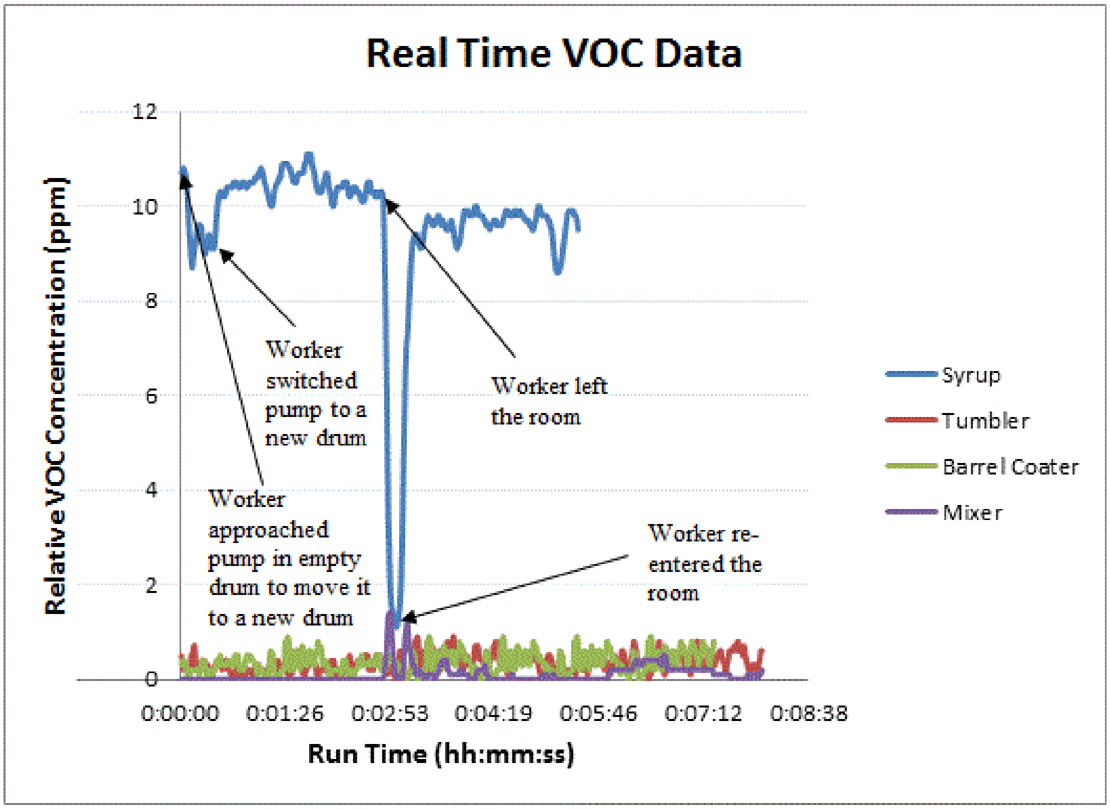


Figure 3. Annular Exhaust for Capturing Vapors During Drum Filling/Emptying. Contains public sector information published by the Health and Safety Executive and licensed under the Open Government License v1.0.

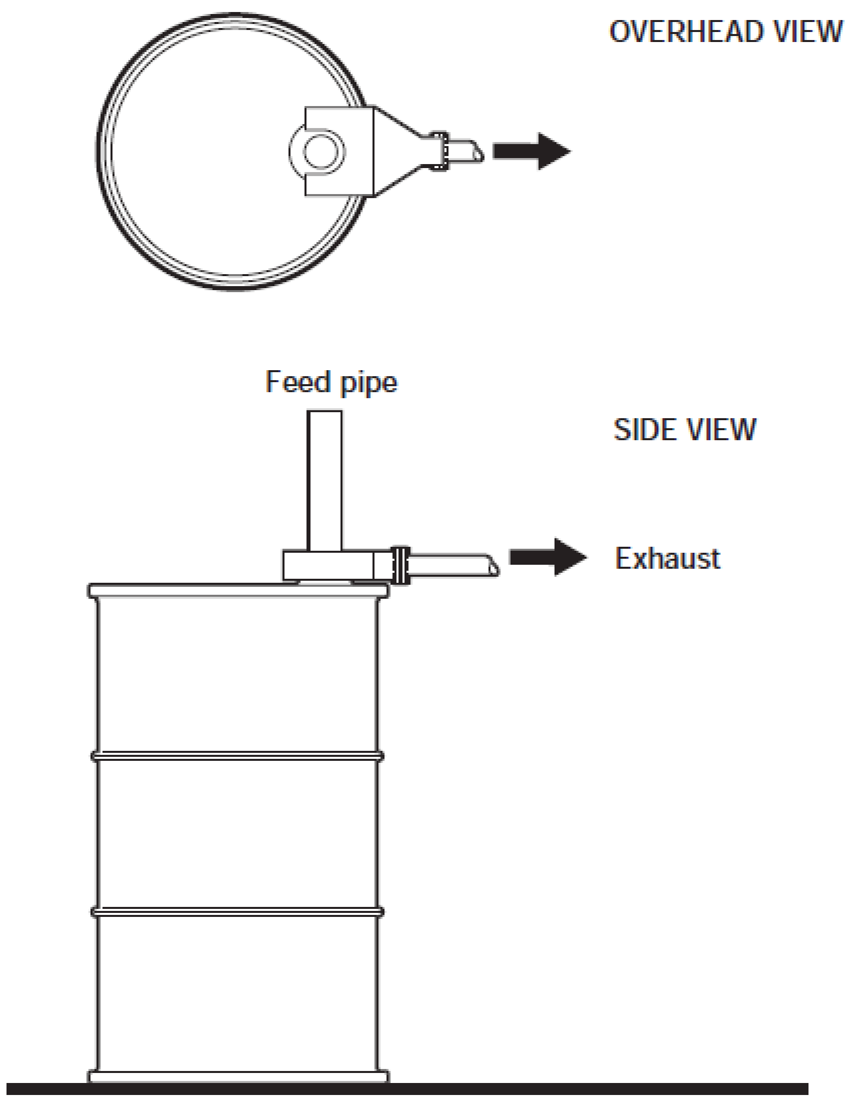
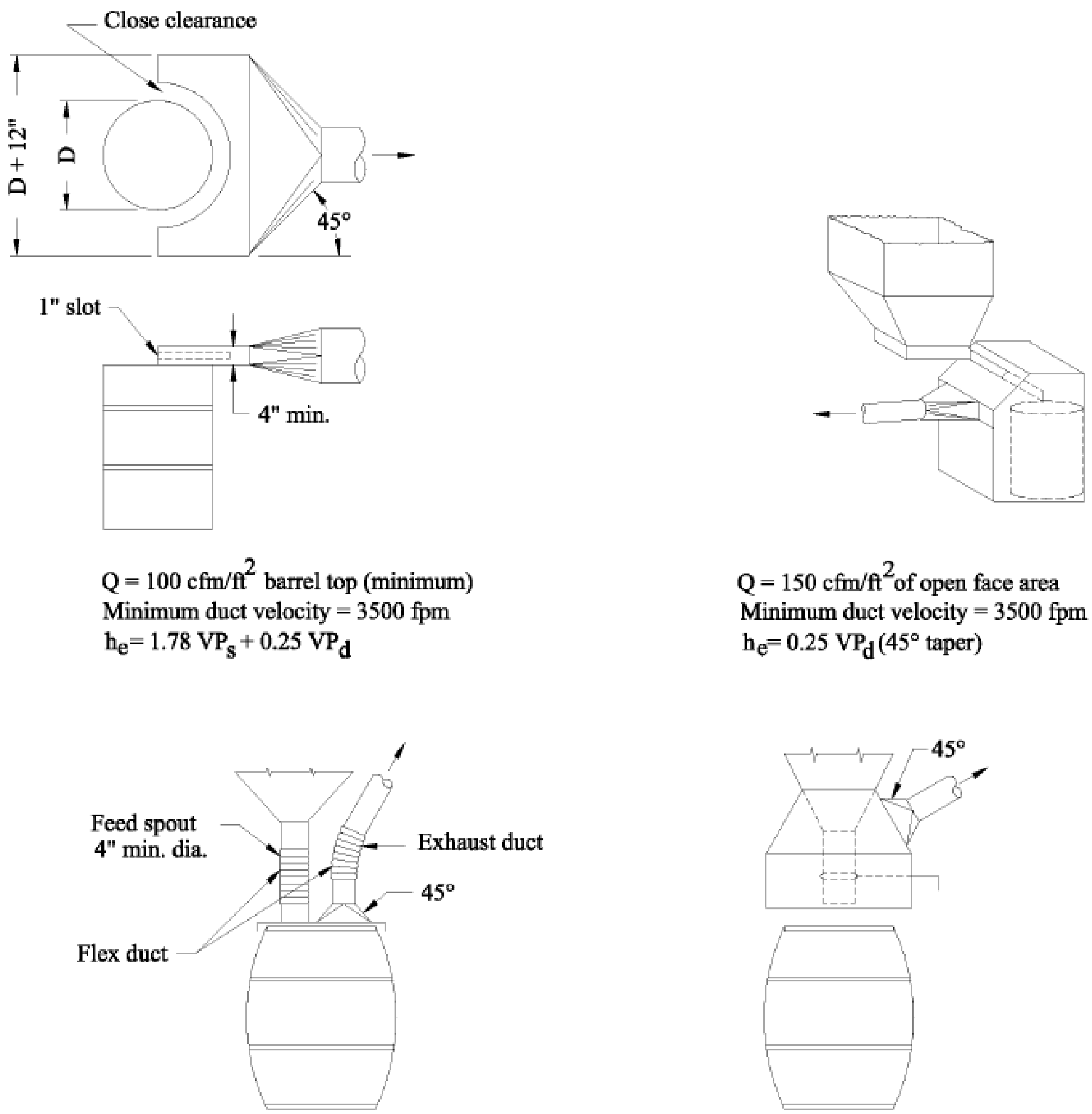


Figure 4. Ventilation Design Options for Capturing Vapors During Drum Filling/Emptying*



$Q = 100\ cfm/ft^2$ barrel top (minimum)
Minimum duct velocity = 3500 fpm
$h_e = 1.78\ VP_s + 0.25\ VP_d$

$Q = 150\ cfm/ft^2$ of open face area
Minimum duct velocity = 3500 fpm
$h_e = 0.25\ VP_d$ (45° taper)

Q = 50 cfm x drum diam. (ft)
Minimum duct velocity = 3500 fpm
$h_e = 0.25\ VP_d$

Q = 300-400 cfm
Minimum duct velocity = 3500 fpm
$h_e = 0.25\ VP_d$

Note 1: Air displaced by material feed rate may require higher exhaust flow rates.

Note 2: Excessive air flow can cause loss of product.

Note 3: When transferring flammable or combustible liquids, bonding and grounding requirements of NFPA Code 77 should be followed.

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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 License v1.0.

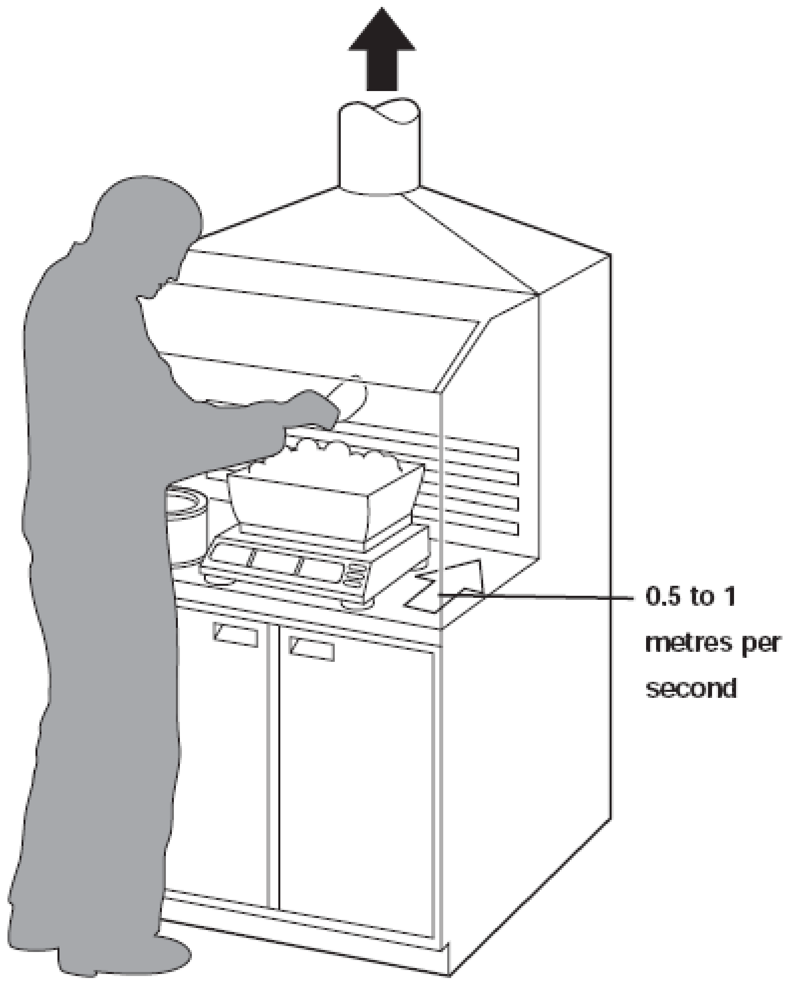

Figure 6. Welding Ventilation Bench Hood.

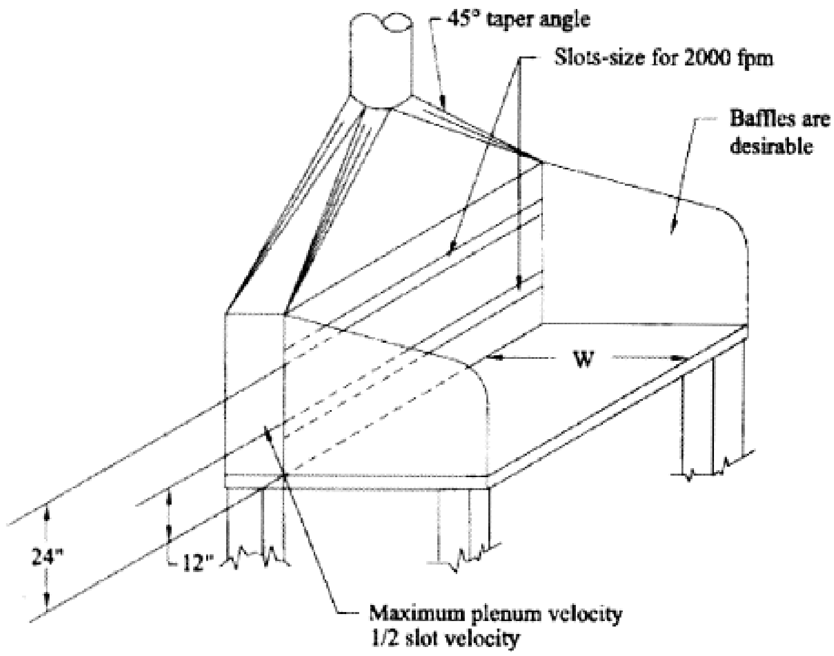

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Figure 7. Ventilated Bag Dumping/Emptying Station, 1.0 mps is equivalent to 200 fpm. Contains public sector information published by the Health and Safety Executive and licensed under the Open Government Licence v1.0.

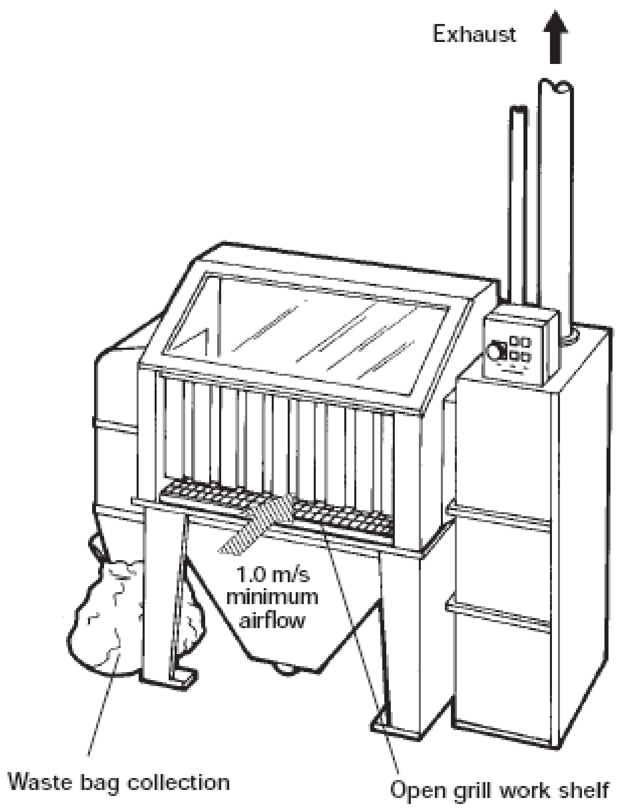

Table 1: Sampling methods for flavoring compounds in food production.

Compound	Analysis Method	Flow Rate	Media	Analytes	LOD[1]
Aldehydes	EPA TO-11a	0.2 L/min	Dinitrophenylhydrazine (DNPH) treated silica	2-Furaldehyde Acetaldehyde Benzaldehyde Isovaleraldehyde Propionaldehyde	0.03 0.01 0.03 0.03 0.03
Acids	Draft NIOSH NMAM 5048	0.2 L/min	Silica Gel (200mg/400mg)	Acetic Acid Butyric Acid Propionic Acid	10 10 10
Ketones	OSHA 1013	0.05 L/min	Silica Gel (200mg/400mg)	Diacetyl Acetoin 2,3 pentanedione 2,3 hexanedione 2,3 heptanedione	1 1 1 1 1
Volatile Organic Compounds	NMAM 2549	0.05 L/min	Thermal Desorption Tubes	VOC screen	n/a
Size Selective Particulates	NMAM 0600	1.5 L/min	37 mm PVC filter	Respirable particulate	40
Bulk Samples	OSHA 1013	n/a	n/a	Diacetyl Acetoin 2,3 pentanedione 2,3 hexanedione 2,3 heptanedione	10 5 10 9 9

[1] Limit of detection (LOD) units are µg/sample except bulk sample which is mg/kg
NMAM = NIOSH Manual of Analytical Methods; n/a = not applicable

Table 2. Area air sample results (μg/m^3)[1]

Date	Sample Location	Location ID	Flavors Handled	Diacetyl	Acetoin	2,3-Pentanedione	2,3-Hexanedione	2,3-Heptanedione	Acetaldehyde	2-Furaldehyde	Benzaldehyde	Isovaleraldehyde	Propionaldehyde	Acetic Acid	Butyric Acid	Propionic Acid	Particulate, Respirable	Thermal Desorption Tube Positive for Diacetyl?
08/17/09	12th floor	03A01A	artificial vanilla ice cream flavor powder 50 lbs x 5/batch	0.0	40.8	0.0	0.0	0.0	81.5	67.4	0.0	9.7	0.8	0.0	0.0	0.0	231.0	no
	9th floor	03A02A	Cargill liquid butter berry type flavor for cereal	0.0	0.0	0.0	645.9	0.0	123.6	9496.3	7.0	3.8	0.0	410.6	3654.4	297.7	2452.2	no
	5th floor, syrup room, inside	03A03A	55 gal drums - nat flavor butter type liq, nat & art maple liq	1889.7	101.4	84.9	0.0	0.0	1893.9	72.4	0.0	11.3	0.0	652.7	0.0	0.0	0.0	yes
	3rd floor	03A04A	nat butter flavor powder 50 lbs box nat & art cheese flavor	0.0	0.0	0.0	0.0	0.0	9.4	0.0	0.0	2.0	0.6	0.0	0.0	0.0	69.1	no
	5th floor, syrup room, outside	03A05A	none	0.0	0.0	0.0	0.0	0.0	16.8	0.0	0.0	1.2	1.4	0.0	0.0	0.0		n/a

08/18/09	12th floor	03A01B	artificial vanilla ice cream flavor powder 50 lbs	0.0	21.3	0.0	0.0	0.0	96.8	40.9	0.0	12.0	0.0	0.0	0.0	66.5	52.8	no
	9th floor	03A02B	Cargill liquid butter berry type flavor for cereal	0.0	0.0	0.0	70.2	0.0	98.3	8319.6	13.6	5.2	0.0	402.5	964.1	149.8	99.5	no
	5th floor syrup room, inside	03A03B	55 gal drums - nat flavor butter type liq, nat & art maple liq	5499.9	0.0	352.3	0.0	0.0	3495.8	45.4	0.0	7.1	0.0	899.6	985.7	181.8	0.0	yes
	3rd floor	03A04B	Givuadin nat & art cheese flavor 50lbs box	0.0	0.0	0.0	0.0	0.0	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	no
	5th floor, syrup room, outside	03A05B	none	0.0	0.0	0.0	0.0	0.0	34.8	0.0	0.0	2.8	0.0	0.0	0.0	0.0		n/a
08/19/09	12th floor	03A01C	bell flavors inc vanilla ice cream flavor powder 50 lbs	0.0	0.0	0.0	0.0	0.0	97.5	76.6	1.0	11.1	2.5	189.5	0.0	0.0	0.0	no
	9th floor	03A02C	Cargill liquid butter berry type flavor for cereal	0.0	0.0	0.0	2314.7	0.0	77.9	10349.9	10.4	18.3	11.8	0.0	141.4	272.7		no
	5th floor, syrup room, inside	03A03C	55 gal drums - nat flavor butter type liq, nat & art maple liq	82.6	0.0	31.0	0.0	0.0	174.9	23.2	0.6	9.9	2.7	207.4	0.0	0.0	0.0	yes

	3rd floor	03A04C	Givuadin nat & art cheese flavor 50lbs boxes, Kerry cheese blend	0.0	0.0	0.0	0.0	0.0	10.3	0.0	0.0	2.9	1.1	0.0	0.0	0.0	0.0	no
	6th floor	03A06A	firmenich n&a cinnamon streusal, givaudan n&a apple and cinnamon flavor, creamer, givaudan blueberry flavor, firmenich blueberry cream	0.0	0.0	0.0	0.0	0.0	38.0	10.8	0.0	0.0	0.0	0.0	0.0	82.5	92.2	no
	6th floor	03A07A	firmenich n&a cinnamon streusal, givaudan n&a apple and cinnamon flavor, creamer, firmenich blueberry cream	0.0	0.0	0.0	0.0	0.0	60.4	20.2	0.6	0.0	0.0	0.0	0.0	0.0	276.2	n/a
08/20/09	6th floor	03A06B	firmenich art peach cream	0.0	0.0	0.0	0.0	0.0	18.3	20.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	no
	6th floor	03A07B	firmenich art peach cream	0.0	0.0	0.0	0.0	0.0	22.9	51.9	0.0	0.0	0.0	0.0	0.0	0.0	105.6	no
	6th floor	03A08A	none	0.0	0.0	0.0	0.0	0.0	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2966.8	n/a

6th floor	03A06C	Firmenich peach cream, Firmenich strawberry cream	0.0	0.0	0.0	0.0	0.0	24.2	18.4	0.0	0.6	0.0	0.0	0.0	0.0	60.1	no
6th floor	03A07C	Firmenich peach cream, Firmenich strawberry cream	0.0	0.0	0.0	0.0	0.0	35.4	52.9	0.0	0.0	0.0	0.0	0.0	0.0	193.5	no

[1] A zero value means the sample was below the limit of detection.

Table 3. Personal air sample results (µg/m³)[1]

Date	Location	Location ID	Flavors Handled	Diacetyl	Acetoin	2,3-Pentanedione	2,3-Hexanedione	2,3-Heptanedione	Acetaldehyde	2-Furaldehyde	Benzaldehyde	Isovaleraldehyde	Propionaldehyde	Acetic Acid	Butyric Acid	Propionic Acid	Particulate, Respirable
08/17/09	12th floor; 9th floor mixing	03P01A	artificial vanilla ice cream flavor powder 50 lbs x 5/batch, butter berry type flavor liq for cereals & strawberry juice concentrate	0.0	0.0	0.0	3246.2	0.0	34.4	381.4	3.8	5.1	0.0	0.0	0.0	87.3	171.9
	3rd floor	03P02A	Cheese blend & nat butter flavor powder 50 lbs boxes	0.0	67.7	0.0	0.0	0.0	12.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08/18/09	12th floor, 9th floor mixing	03P01B	artificial vanilla ice cream flavor powder 50 lbs x 5/batch, butter berry type flavor liq for cereals & strawberry concentrate	0.0	0.0	0.0	114.9	0.0	34.7	797.1	3.9	4.6	0.0	0.0	150.5	75.3	0.0

08/19/09	12th floor, 9th floor mixing	03P01C	artificial vanilla ice cream flavor powder 50 lbs x 5/batch, butter berry type flavor liq for cereals & strawberry juice concentrate	0.0	30.1	0.0	381.0	0.0	23.0	424.8	5.2	5.2	3.0	0.0	0.0	0.0	0.0
	3rd floor	03P02B	Givaudan n&a cheese flavor	0.0	0.0	0.0	0.0	0.0	21.8	8.0	0.0	2.2	2.1	0.0	0.0	0.0	0.0
	6th floor	03P03A	Blueberry cream	0.0	22.5	0.0	0.0	0.0	37.0	11.1	1.0	0.0	0.0	0.0	0.0	0.0	191.5
08/20/09	6th floor	03P03B	none	0.0	0.0	0.0	0.0	0.0	11.7	15.0	0.5	0.0	0.0	0.0	0.0	0.0	875.8
	6th floor	03P04A	none directly	0.0	0.0	0.0	0.0	0.0	10.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1662.7
08/21/09	6th floor	03P03C	Firmenich peach cream flavor. Firmenich strawberry cream flavor	0.0	0.0	0.0	0.0	0.0	32.7	35.1	2.1	0.0	0.0	0.0	0.0	0.0	224.9

[1] A zero value means the sample was below the limit of detection.

Table 4. Bulk sample results (mg/kg)[1]

Sample ID	Flavor	Type	Diacetyl	Acetoin	2,3-Pentanedione	2,3-Hexanedione	2,3-Heptanedione
03B50A	cheese	P	0	0	0	0	34
03B51A	cheese blend	P	0	57	0	0	54
03B52A	blueberry cream	P	0	0	0	0	0
03B53A	creamer	P	0	0	0	0	0
03B54A	vanilla ice cream	P	3300	0	0	0	0
03B55A	peach cream	P	0	0	0	0	0
03B56A	butter berry	L	990	0	0	0	0
03B57A	strawberry juice concentrate	L	0	0	0	0	0
03B58A	natural butter	L	4000	4500	460		0
03B59A	natural & artificial maple	L	0	0	0	0	0
03B60A	strawberry cream	P	0	0	0	0	0

[1] A zero value means the sample was below the limit of detection.
L = liquid, P = powder

Table 5. Occupational exposure limits.

Chemical	OSHA Permissible Exposure Limit (PEL)	NIOSH Recommended Exposure Limit (REL)	ACGIH Threshold Limit Value (TLV)
Acetoin	None	None	None
Diacetyl*	None	None	None
2,3-Heptanedione	None	5 ppb (0.02 mg/m^3) TWA, 25 ppb (0.09 mg/m^3) STEL	None
2,3-Hexanedione	None	None	None
2,3-Pentanedione*	None	9.3 ppb (0.04 mg/m^3) TWA, 31 ppb (0.13 mg/m^3) STEL	None
Acetic Acid	25 mg/m^3 TWA	25 mg/m^3 TWA, 37 mg/m^3 STEL	25 mg/m^3 TWA, 37 mg/m^3 STEL
Butyric Acid	None	None	None
Propionic Acid	30 mg/m^3 TWA	30 mg/m^3 TWA, 45 mg/m^3 STEL	30 mg/m^3 TWA
Acetaldehyde	360 mg/m^3 TWA	Potential occupational carcinogen, minimize exposure	45 mg/m^3 ceiling
Benzaldehyde	None	None	None
Isovaleraldehyde	None	None	None
Propionaldehyde	None	Potential occupational carcinogen, minimize exposure	47.5 mg/m^3 TWA
2-Furaldehyde	20 mg/m^3 TWA (skin)	None	7.9 mg/m^3 TWA (skin)
Particulate, Respirable	5 mg/m^3 TWA	None	3 mg/m^3 TWA

* The proposed NIOSH RELs for diacetyl and 2,3-pentanedione are currently in draft and are not final.
TWA (time weighted average): Average exposure concentration for an 8 hour workday and 40 hour workweek.
STEL (short term excursion limit) A 15 minute TWA exposure concentration that cannot be exceeded at anytime.
Ceiling (ceiling limit): The exposure concentration that should not be exceeded at anytime

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