

NIOSH TECHNICAL REPORT

CONTROL TECHNOLOGY ASSESSMENT OF
ENZYME FERMENTATION PROCESSES

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ABSTRACT

A control technology assessment of enzyme fermentation processes was conducted by researchers from the National Institute for Occupational Safety and Health (NIOSH) to identify effective controls applicable to process microorganisms, intermediate processing chemicals, and biologically active products. This assessment will help to establish a baseline of information, where there is currently none, on the equipment and related occupational safety and health programs and practices used in enzyme fermentation processes. Walk-through surveys were conducted at 8 biotechnology plants and in-depth surveys were conducted at 3 of the plant sites selected during the walk-through surveys. Area aerosol samples were collected for viable process microorganisms, enzymes, and total dust around potential emission sites. These sites included the laboratories, seed and fermentor tanks, and filtering operations. The results indicate that the controls are most needed around high energy operations where aerosolization is likely to occur such as filtering operations, agitator shafts, and sampling ports. Exhaust gases from the seed and fermentor tanks are another major emission site and should be controlled with an effective filtering system. Also, worker practices can be a determining factor influencing the degree of exposure.

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INTRODUCTION

The 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 (formerly DHEW), it was established by the Occupational Safety and Health Act of 1970. This legislation mandated that NIOSH conduct research and education programs separate from the standard setting and enforcement functions conducted 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 Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study the engineering aspects relevant to health hazard prevention and control.

NIOSH's research responsibility extends to both existing and emerging technologies which may affect worker health and safety. The attempt to examine new technologies for potential occupational hazards specifically focuses on those technologies which have high growth potentials or for which exposures to particular agents have not been fully characterized. NIOSH has been instrumental in the development of recommendations for safeguarding workers' safety and health from exposure to occupational hazards. Implementation of safeguards and protective engineering controls early in the growth of an industry will minimize occupational safety and health problems and avoid expensive retrofitting of production systems.

NIOSH researchers have been evaluating the potential hazards (and their control) involved with the applications of biotechnology and recombinant DNA (rDNA). Previous NIOSH research into biotechnology includes a study of six companies employing rDNA techniques in their research activities or their production operations. A report of this research, conducted by the Division of Surveillance, Hazard Evaluation, and Field Studies (DSHEFS), was published as an article entitled Medical Surveillance of Recombinant DNA Workers: Report of the CDC/NIOSH Ad Hoc Working Group on Medical Surveillance for Industrial Applications of Recombinant DNA.¹ In addition, DSHEFS conducted an occupational and general public exposure characterization of a large-scale land application of the microbial pesticide Bacillus thuringiensis (Bt) in Portland, Oregon.²

The study conducted by ECTB, reported herein, is an assessment of the control technology being employed to minimize occupational health hazards in the enzyme fermentation industry. The study focused on conventional enzyme fermentation process operations. Several factors contributed to the final decision to focus this research project. First, the products manufactured in the overall fermentation industry, although dissimilar entities, are produced using a somewhat standardized process technology. Product recovery operations may vary with the product properties, source microorganisms, and base solvents used, but the basic fermentation technology remains essentially the same. Second, the diversity of the fermentation industry requires different environmental air sampling and analytical methodologies for each product and process microorganism studied. Narrowing the field of investigation satisfies the need to limit the "products" studied in order to minimize the number of

sampling and analytical methods to develop. Lastly, there is a good probability of finding well controlled processes in the enzyme industry since enzymes are associated with health effects.

It was been estimated that the world market for industrial enzymes produced by microorganisms represents a sales value of \$150-175 million with an annual production of over 1190 tons of pure enzyme protein. More than a thousand different enzyme patents have been applied for, in contrast to the less than 50 microbial enzymes that are currently of industrial use. This comparison of patent applications to the limited number of industrially used enzymes reflects the rapid increase in this technological field.^{3,4} Estimates, to 1985, had placed the total market value of enzymes at \$500 million.⁵ Recombinant DNA could play a major role in this industrial growth, permitting not only the production of purer forms and larger quantities of existing enzymes, but also expanding enzymatic applications found predominantly in the food industry to the pharmaceutical and chemical industries. This growth will likely increase the number of persons engaged in enzyme production, thereby increasing the number of persons exposed to the potential hazards of that production.

This control technology assessment of enzyme fermentation processes is intended to identify and document effective controls applicable to processes involving microorganisms, processing chemicals, and biologically active products or intermediates. Recognizing that the enzyme industry represents only a small segment of the biotechnology industry, this evaluation will help to establish a baseline of information on the equipment (and related safety and health programs and practices) currently used in enzyme fermentation operations. This baseline of information can then be transferred to other fermentation technologies -- those involved with rDNA techniques to mutate microorganisms or those utilizing conventional techniques (e.g. natural selection, ultraviolet light, etc.) to mutated microorganisms.

HEALTH HAZARDS AND EXPOSURE CRITERIA

The potential for exposure to hazards within the enzyme industry, as within the overall fermentation industry, is three-fold. Workers may be exposed to potentially hazardous microorganisms, biologically active products or intermediates, and processing chemicals.

MICROORGANISMS

Presently, the microorganisms used by the enzyme industry for fermentation operations are nonpathogenic in nature. However, future use of rDNA techniques may produce microorganisms that may require more stringent containment and equally stringent programs in occupational safety and health due to the increased health risks that they may pose to the workers. However, the pathogenicity of a microbe, innate or genetically modified, is not the only occupational health concern. Increasing attention is being focused upon the potential for immunologic response, after repeated inhalation, to a variety of organic materials. Cases of hypersensitivity pneumonitis have been documented in individuals exposed, in the occupational environment, to fungi, thermophilic actinomycetes, as well as animal proteins. A survey of 4023

office workers (Arnow et al.) cited 48 suspect cases, along with three laboratory confirmed cases, of hypersensitivity pneumonitis related to a contaminated open spray water air cooling system.⁶ Topping et al. documented clinical and immunological reactions to Aspergillus niger among workers at a Citric Acid manufacturing plant.⁷ Banazak et al. reported symptoms of cough, dyspnea, malaise, fever, and rales in 85 symptomatic subjects exposed to antigenic microorganisms in the home environment.⁸ Numerous other case studies document the sensitizing potential of airborne microorganisms in susceptible persons.^{9,10,11}

PRODUCTS OR INTERMEDIATES

The biological activity of the final or intermediate products of fermentation processes to workers is presently the primary health concern within the enzyme industry. The enzyme molecule consists of a chain of amino acids arranged in a specific geometric configuration. This protein structure, as is the case with many proteinaceous materials, will cause immunologic responses in susceptible persons if these antigens are inhaled. Repeated inhalation of enzyme dust may provoke respiratory allergies (hay fever, asthma) or illnesses (rhinitis) in individuals who have become sensitized to a specific protein structure of an enzyme. Flindt was among the first to investigate chest illness in certain workers exposed to preparations containing proteolytic enzymes, derived from *Bacillus subtilis*, in the manufacture of detergents.¹² Weill et al. reported in a study of two detergent manufacturing plants common sensitization reactions among exposed workers including occurrences of symptoms which typically involved cough, wheezing, chest tightness, and dyspnea.¹³ Frequently, an atopic history could be associated with symptomatic workers. Numerous other reports implicate the potential respiratory hazards occurring from exposure to enzymes.^{14,15,16,17,18} Sensitization reactions may vary from mild to severe, depending upon the particular individual exposed. Some enzymes (proteolytic), have been shown to cause contact dermatitis to exposed areas of moist skin, eyes, and mucous membranes.¹⁹ The majority of documented case studies of persons exposed to enzymes has focused upon the immunologic responses due to the inhalation or skin irritation due to contact with enzymatic dusts. There appears to be limited available literature pertaining to individuals exposed to aerosolized solution enzymes. However, there is no reason to believe that the effects from contact to or inhalation of aerosolized solution enzymes is appreciably different from the effects of similar exposures to enzyme dusts.

The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a Threshold Limit Value (TLV) of 0.8 Delft Units (DU) per m³ of air of subtilisins (a proteolytic enzyme produced by the bacteria *Bacillus subtilis*) over an eight hour work shift.²⁰ A DU is calculated from the amount of proteolytic enzyme that is required to act on a protein substrate in a specified amount of time.

PROCESSING CHEMICALS

Intermediate processing chemicals pose another potential hazard in fermentation operations. In the enzyme manufacturing industry, these processing chemicals include filter aids, acids, and caustics. One such

filter aid is diatomaceous earth (amorphous silica) commonly used as a precoat for various filtering operations during the product extraction processes. Amorphous silica can affect the body if it is inhaled or if it comes in contact with the eyes. Prolonged inhalation of amorphous silica including uncalcined diatomaceous earth may produce x-ray changes in the lungs without disability. Prolonged inhalation of calcined diatomaceous earth may cause silicosis with scarring of the lungs, cough, and shortness of breath. The current Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) standard for amorphous silica is the quotient of 80 mg/m³ divided by the percent of silica present.²¹ ACGIH recommends a maximum Time Weighted Average (TWA) exposure of 1.5 mg/m³ of respirable amorphous silica.²⁰

Acids and bases are used to adjust pH levels of culture broth mixtures or concentrated enzyme liquids throughout the enzyme production process; both will cause burns. Acids are corrosive, irritating, and can cause burns. Base compounds are caustic and can also cause burns.

In some instances, acetone may be used during the recovery of the liquid enzyme product from the microbial culture broth. Repeated contact exposure (percutaneous absorption) to acetone may produce dry, scaly, and fissured dermatitis. Inhalation of high concentrations of acetone vapors may irritate the conjunctiva and mucous membranes of the nose and throat. Systemic reactions to high concentrations include headaches, nausea, light headedness, vomiting, dizziness, incoordination, and unconsciousness. The current OSHA PEL for acetone is a TWA of 1000 ppm.²¹ The current NIOSH Recommended Exposure Limit (REL) is 250 ppm.²² ACGIH recommends a maximum TWA exposure of 750 ppm for acetone.²⁰

Limited information is available in the literature concerning the degree of containment, in original or modified form, of these fermentation related hazards. The National Institutes of Health has established guidelines specifically addressing research involving rDNA molecules.²³ An appendix to these guidelines, focusing on large-scale research and production, outlines specifications for the containment of genetically altered microorganisms in cultures greater than 10 liters. Studies of control technology related to enzyme production predominantly report on the containment of the solidified, finished product prior to industrial or commercial use.^{24,25} There is limited documentation of controls at the production level. The same is true of the intermediate processing chemicals.

This lack of information only reinforced the need for an assessment of effective systems of hazard control measures in the enzyme industry that might be transferable to or representative of the overall fermentation industry. The anticipated expansion of these industries and increased use of fermentation processes will rely heavily on existing fermentation process technology with respect to equipment design and effective containment of the potential hazards. An examination of the controls, in existing fermentation processes can facilitate the assessment of current technology and help evaluate the adequacy of this technology when applied to rDNA scale-up operations.

PROCESS DESCRIPTION

This study included the evaluation of three main phases of the enzyme manufacturing process: Laboratory and Inoculation (or microbial preparation and growth), Fermentation (or product biosynthesis), and Process Recovery (or product extraction and purification). A process flow diagram is shown in Figure 1. Other process steps, such as the selection or cultivation of a desired strain of microorganism (including the maintenance of the selected culture) and the final packaging of the finished product, occupied minor roles in this research investigation.

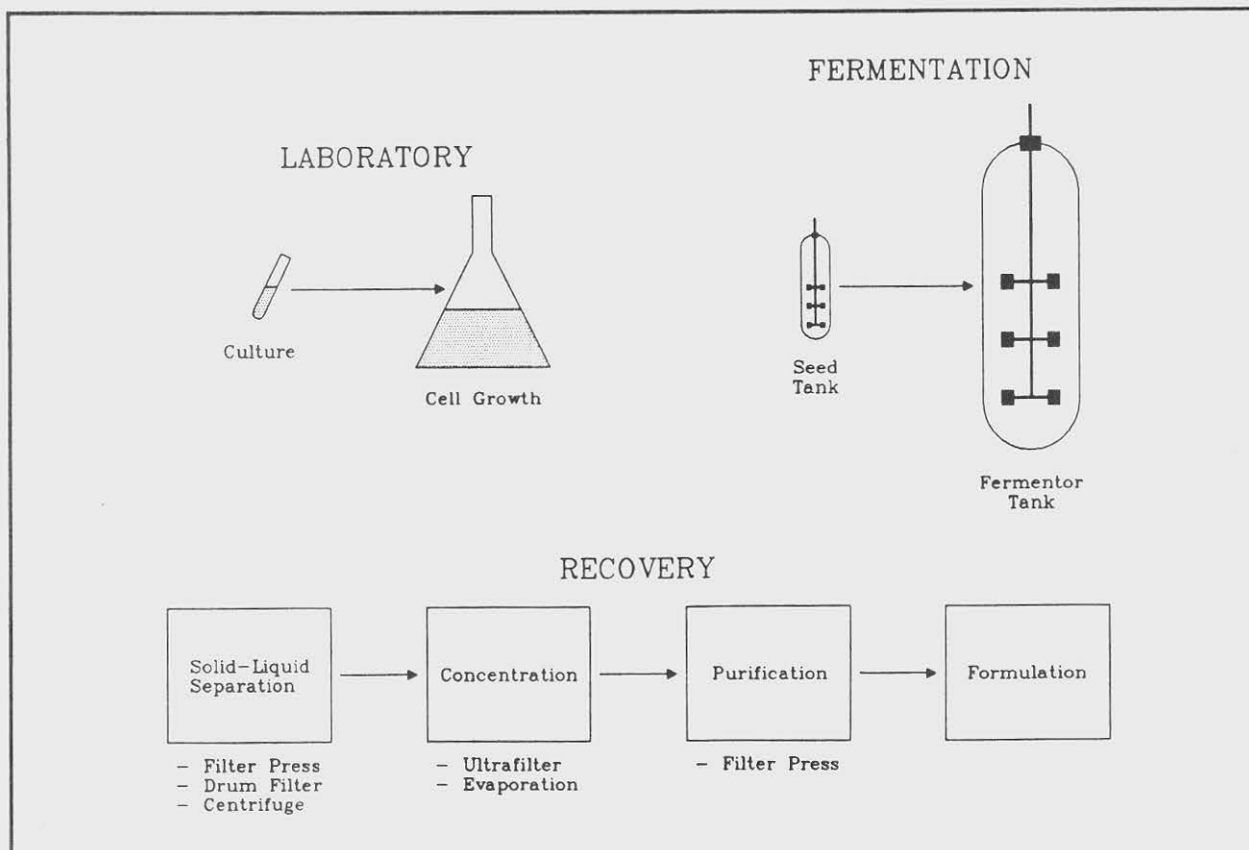


Figure 1. Enzyme Fermentation Process Description.

LABORATORY AND INOCULATION PHASE

The Laboratory and Inoculation Phase is initiated by development, preparation, and growth of selected cultures of microorganisms that are accomplished prior to transfer for a large-scale fermentation. All pertinent microbiological operations within the laboratory are conducted using sterile equipment with aseptic transfer techniques. Selected cultures are grown (initially from stock cultures then propagated in shaker flasks), harvested, subdivided, and then stored at appropriate conditions to maintain viability and purity. To reduce the risk of contamination with foreign microorganism strains, successive recultivations of cultures and numerous propagation steps are held

to a minimum. After initial preparation, the microbial cultures are transferred and aseptically inoculated into a seed tank for the first segment of the fermentation process phase.

The raw materials used for the nutrient preparation in the fermentation process phase are generally well controlled to prevent contamination that would inhibit organism growth and/or enzyme production; also these raw materials should not contain toxic or harmful compounds that could be carried through the process into the final product. If the enzymes manufactured are to be used with food products, the raw materials must be of food grade quality. The nutrient medium is an energy source for the fermentation process and requires raw materials containing carbon, nitrogen, and special growth factors, such as essential amino acids. Stimulating compounds can be added to increase the growth rate or to reduce the lag time in the growth curve of microorganisms. Sterilization of the medium is accomplished on a batch basis (typically by steam infusion) in both the seed and fermentor tanks.

FERMENTATION PHASE

In the Fermentation Phase, multiple propagation steps are again held to a minimum to reduce the possibility of contaminating large quantities of culture media and to optimize the use of process equipment. The seed tank, containing the sterile nutrient medium, is inoculated with the selected microbial culture prepared in the laboratory. The seed tank is designed to promote the growth of the microbial population to the level necessary for proper inoculation of the fermentor tank. The batch mixture in the seed tank is aerated and mechanically agitated until the optimum level of culture growth is achieved. Upon completion of the cycle, the contents of the seed tank are aseptically transferred to a larger seed tank or, as is generally the case, directly to the fermentor tank, where "fermentation" occurs and the product of interest is biologically synthesized. A submerged, batch fermentation process is usually employed using a standard deep-tank reactor vessel with a top-mounted mechanical agitator and a bottom air sparger. Proper temperature conditions are maintained with cooling coils inside (or a cooling jacket around) the reactor vessel. The fermentor tank, containing the pre-sterilized nutrient medium from a batching tank and the inoculant microbial culture broth mixture from the seed tank, is aerated and mechanically agitated for continued microbial growth and final fermentation of the desired enzyme. The composition of each seed and fermentor tank is carefully monitored and controlled to promote maximum growth of the microorganisms and/or maximum enzyme production.

PROCESS RECOVERY PHASE

After the fermentation process phase, the broth is rapidly cooled and then combined with filter aids. The enzyme product liquid is extracellular and is extracted from the microbial culture broth via solid/liquid separation techniques. These separation techniques are simple unit operations such as centrifugation, filtration, vacuum evaporation, and precipitation of proteins. The enzyme broth is further concentrated with ultrafiltration and then purified (polished) with a bacterial filter to remove unwanted bacterial contamination. Continuous monitoring of the process is necessary to ensure

that it is economic and that, where applicable, that the final enzyme product will be of food grade quality. The majority of enzyme products are packaged in liquid form. However, some enzymes are dried and sold as a solid (e.g. proteolytic enzymes used in laundry detergents).

CONDUCT OF FIELD STUDIES

SITE SELECTION

Preliminary walk-through surveys were conducted at sites which were reported to have well controlled production processes for the hazards of interest; microorganisms, enzymes and intermediate processing chemicals. These site visits were conducted to subjectively evaluate the control systems in place. When these preliminary surveys were completed, they were reviewed to determine which plants would be contacted to schedule in-depth studies. This determination was based on the type of material processed and the apparent quality and uniqueness of the control in place. All site visits were conducted according to the NIOSH Regulations for Investigations of Places of Employment, Code of Federal Regulations (CFR), Title 42, Part 85a. Each company was contacted in advance of the planned site visit and provided details about the project.

PRELIMINARY SURVEYS

Eight preliminary walk-through surveys were conducted. In general, a complete survey was usually accomplished in a one day visit. One to three engineers and/or industrial hygienists conducted each preliminary survey. The survey began with a meeting to discuss the details of the site visit with representatives of both management and labor. During this introductory meeting, the survey team reviewed the study and answered questions. The team then began to observe and collect information, starting with a tour of the pertinent process areas.

Each preliminary survey involved an evaluation of the various components in a complete hazard control system, including: engineering controls (material substitution, process substitution, local and general ventilation); employee work practices (preventive maintenance on equipment or controls, housekeeping, administrative controls); personal protective equipment; and industrial hygiene monitoring (personal exposure monitoring, environmental monitoring, medical/biological examination and monitoring). No environmental air sampling was conducted. Photographs were taken to help the team recall the physical configuration of the production facilities. These observations aided in selecting the sites for in-depth studies and in refining the experimental design for each individual in-depth study. In most cases, at the end of the tour, the team held a closing meeting with management and labor for last minute questions or comments.

In-depth survey sites were selected from the population of preliminary surveys based on the researchers' subjective assessment of the ability of plant equipment to contain viables, products, and/or processing chemicals. In addition, prioritization was given to plants utilizing innovative methods and/or recently installed manufacturing equipment.

IN-DEPTH SURVEYS

Three in-depth surveys were conducted. Prior to each of these in-depth surveys, an exploratory survey was conducted to assess background concentration levels of viable microorganisms. These background concentration levels were necessary for the determination of in-depth viable air sampling parameters such as; sample locations, control sample locations, sample times, and sample frequency. The samples were collected with an Andersen 2-stage microbial sampler proximate to operations of specific interest -- locations of potential aerosol release. These included the inoculum tank, the fermentor tank, filtering operations, and the laboratory. Sampling times varied from 2.5 minutes to 20 minutes at a flowrate of 28.3 liters per minute (lpm). The viable sampling required 2 to 3 work days and additional days were required for colony counts and strain identification. Colony counts and strain identification were conducted on-site.

Before collecting the data for the exploratory surveys, the team made a brief tour of those production facilities related to the study. This also provided an opportunity for the company to precisely identify any proprietary information which might be involved in the investigation and other safety precautions for the team to observe while they were in the plant. This tour also enabled the team to refresh their understanding of the relationship between the operation of interest and the rest of the facility.

A team of six or seven researchers conducted each in-depth survey. This team consisted of five or six engineers and industrial hygienists, a microbiologist, a biologist, and a chemist. Environmental air samples (area sampling, background monitoring, and source monitoring for total dust, enzymes, and viables) and other measurements (hood face-velocity measurements, duct velocities, where applicable, and general airflow measurements) and information were gathered to document the level of control achieved. The environmental air samples were collected at strategic locations believed to duplicate workplace exposures and/or to indicate emission sources. A descriptive summary of the equipment used during each survey is listed in Table 1. Also, the team talked with some of the employees to collect information concerning individual job duties. A full work week was required to complete the environmental air sampling of each in-depth survey. Three members of the survey team (including the microbiologist and the biologist) remained 2 or 3 additional days to analyze the microbial air samples for colony counts and strain identification.

Viable Sampling and Analysis

To determine concentrations of airborne microorganisms around unit processes, the Andersen 2-stage viable sampler was used at a flow rate of 28.3 liters per minute (lpm). The 50% effective cutoff diameter for the top stage of the Andersen viable sampler is 8.0 μm -- therefore, larger, potentially nonrespirable particles are collected on the top stage, and smaller, potentially respirable particles are collected on the bottom stage. Standard Methods Agar was used as the sampling media in each stage of the viable sampler.²⁶ Sampling for bioaerosols was conducted in the laboratory; around the inoculum tank, fermentor tank, and product recovery operations; and in

areas outdoors and indoors selected to give approximations of normal background levels. Some samples were conducted side-by-side to monitor variability of the microbial air samplers.

Table 1. Equipment Used on Field Survey

Item	Model	Purpose
Air velocity meter	Kurz	Hood face velocity and flow measurements
Automatic balance	Mettler AE 163	Gravimetric analysis
Automatic psychrometer	Vista Scientific Corporation	Temperature and humidity measurements
Colony Counter	New Brunswick Scientific	Colony counts and identification
High-volume air sampler with a 8.5" by 11" glass fiber filter	General Metal Works	Enzyme and total dust sampling
Personal sampling pump attached to 35 mm cassette with a PVC filter ³²	Dupont 2500	Total dust sampling
Personal sampling pump attached to charcoal tube ³²	Dupont P-200	Acetone sampling
Smoke tubes	Draeger	Air flow patterns
Viable cascade impactor	Andersen 2-stage	Bioaerosol sampling

The samples were collected over a five day period to detect day-to-day variability, if any. Sample times varied from 20 minutes down to 2.5 minutes depending on the sample location. For example, a sampling time of 20 minutes was used in areas where microbial concentrations (e.g. the laboratory) were expected to be low and a 2.5 minute sampling time was used in areas of high microbial concentration (e.g. around filtering operations).

Microbiological analysis of the viable samples was conducted on-site. The primary goal of this analysis was to quantify the numbers of the production microorganism in the air at different locations in the plant. All air sampling plates were counted at 24 hours using standard colony counters. Colonial morphology was compared with that of the production strain of the same age and on the same medium. Where possible, colonies resembling the production strain were included as a separate count. A percentage of these typical colonies were streaked to Standard Methods Agar for isolation and identification. Colonies were identified by gram stain and/or the Rapid CH kit manufactured by API System, S.A. This identification scheme consists of 49 biochemical tests read at 24 and 48 hours.²⁷ Results were compared to the Rapid CH profile of the index strain (process microorganism). Each step of the microbial identification process by itself is not an absolute indicator of

the production strain. However, combining the results of these identification tests provide the microbiologist with the information needed to produce reliable conclusions concerning the presence or absence of the production strain.

Sample results are presented in terms of Colony-Forming Units per cubic meter of air (CFU/m³) with percentages of the production strain, where available. Sample concentrations around process operations are compared to background samples to help ascertain the degree of microorganism release from manufacturing processes.

Outside background samples were grouped into a single classification. Any effects on outside background samples due to viable process emissions were assumed to be uniform from sample location to sample location. Sample numbers between locations were unequal and, at times, numbers of samples were small -- ranging from 2 to 56. All results were blank corrected and assumed to be log normally distributed based on statistical tests that check for normality.

Viable sample concentrations, collected around selected unit processes, were compared (using the pooled Student's t-statistic for comparing two means) to background to ascertain the degree of containment of those processes. Analysis of the relationships between unit processes among plants was conducted to assess the effectiveness of the engineering controls. Tukey's test for all main-effect (sample location) means was employed to determine any statistically significant differences among unit processes. This statistical test is based on a Studentized range for comparison of pairs that controls the maximum experimental error rate.^{28,29,30} Causes of significant differences were subjectively identified based on the researchers' knowledge of the process equipment and observation of the engineering controls.

Enzyme Sampling and Analysis

Environmental monitoring of the airborne enzyme concentrations was conducted using General Metalworks high-volume samplers and high efficiency (pre-weighed) 8" by 10" glass fiber filters at a flow rate of approximately 1132 lpm. The samplers were strategically positioned at fixed locations in the plants best suited to estimate exposure conditions and isolate points of enzyme aerosol release. Samples were collected for eight hour workshifts over a four day period. Analysis of the enzyme samples was conducted on-site.

Due to complications with the analytical method for the detection of enzymes, specifically α -amylase, results for Plant 2 and Plant 3 were unavailable. The major complications included a method lacking the desired sensitivity to detect α -amylase and the degradation of the enzyme molecule caused by the airflow through the filter of the sampling instrument.

For proteolytic enzymes, the 8" x 10" glass fiber filters were weighed before sampling on a Mettler AE 163 balance. The instrumental precision for one sitting is 0.01 milligrams (mg). After sampling, the filters were equilibrated in the laboratory environment (cooled and dehumidified) and reweighed on the same balance. The difference in filter weights were recorded as total dust weight per filter. After gravimetric analysis, each filter was

agitated with a sonic bath in 100 ml of sodium tripolyphosphate/Brig 35 solution to elute the proteolytic enzyme from the filter. The remaining liquid was passed through a 0.45 μ m PTFE filter.

Samples and standards in duplicate were reacted with the substrate and incubated under stringent temperature, pH, and time controls as prescribed in the protease enzyme activity method.³¹ Standards were prepared from a protease of a known Delft Unit (DU) per gram. After an incubation period, the reaction was stopped, excess protein precipitated, and the absorbance of the supernatant measured on a spectrophotometer at a wave length of 275 nanometers (nm). A calibration curve was prepared daily for each set of samples using a polynomial regression program on all of the calculations. The lower limit of detection and the lower limit of quantitation were determined from plots of the media blanks and the three lowest standards on one curve. The lower limit of detection is defined as the amount of material that can be distinguished from the blanks -- determined to be 50 DU per filter. The lower limit of quantitation is defined as the concentration that has an imprecision greater than 10% and is routinely three times the limit of detection or 150 DU per filter.

Total Dust Sampling and Analysis

Total dust samples were collected, in addition to the total dust measurements obtained from the enzyme samples, on 37 mm, 5 μ m pore size Polyvinyl Chloride (PVC) filters at an approximate flow rate of 2.5 lpm with Dupont 2500 pumps according to the NIOSH method No. 0500.³² Samples were collected for eight hour workshifts over a four day period. The pumps were calibrated prior to the field survey. Sample locations included material dump stations, most areas where viable and/or enzyme samples were located, and those areas believed to approximate background dust levels for the plant.

The PVC filters were pre-weighed in the plant laboratory (on a Mettler AE 163 balance) and re-weighed under the same conditions after sampling. The difference between the initial weight and the weight after sampling was recorded as total weight per filter.

Other Air Sampling

Acetone samples (only at the first plant) were collected according to NIOSH method 1300.³² Sample locations were focused around the product recovery area, for one hour intervals during times when the process was in operation and airborne levels would be expected to be at their highest. Samples also were collected at other locations within the acetone recovery area. Samples were collected with Dupont P-200 pumps at a flow rate of 50 milliliters per minute (ml/m) through standard 150 mg charcoal tubes. The pumps were calibrated prior to the field survey. After sampling, the charcoal tubes were desorbed for 30 minutes in 1.0 ml of carbon disulfide containing 1 μ l/ml of hexane as an internal standard. A Hewlett-Packard gas chromatograph (model 5711A) equipped with a flame ionization detector was used for sample analysis. The Column was a 12' x 1/8" stainless steel, 10% TCEP on 80/100 Chromosorb P (AW). Oven conditions were set at 80°C, isothermal. Sample locations (at the first plant) were focused around the filter press, for one hour intervals

during times when the filter press was in operation and airborne levels would be expected to be at their highest. Samples were also collected at other locations within the acetone recovery area.

RESULTS/DISCUSSION

Occupational exposures can be controlled by the application of a number of well-known principles, including engineering measures, work practices, personal protection, and monitoring. These principles may be applied at or near the hazard source, to the general workplace environment, or at the point of occupational exposure to individuals. Controls applied at the source of the hazard, including engineering measures (material substitution, process/equipment modification, isolation or automation, local ventilation) and work practices, are generally the preferred and most effective means of control both in terms of occupational and environmental concerns. Controls which may be applied to hazards that have escaped into the workplace environment include dilution ventilation, dust suppression, and housekeeping. Control measures can also be applied to keep hazard emissions from exposing individual workers including; the use of remote control rooms, isolation booths, supplied-air cabs, work practices, and personal protective equipment. In the fermentation industry, a debilitated (weakened) production strain also can be an effective means of reducing the microbial level around unit process operations.

In general, a system comprised of the above control measures is required to provide worker protection under normal operating conditions as well as under conditions of process upset, failure, and/or maintenance. Process and workplace monitoring devices, personal exposure monitoring, and medical monitoring are important mechanisms for providing feedback concerning the effectiveness of the controls in use. Ongoing monitoring and maintenance of controls to insure proper use and operating conditions, and the education and commitment of both workers and management to occupational health are also important ingredients of a complete, effective, and durable control system. These principles of control apply to all situations, but their optimum application varies from case to case. This section will present the results of this study and how these results reflect the effectiveness of the controls to contain the process microorganisms, products, or intermediate processing chemicals for each plant.

ENGINEERING CONTROLS

The enzyme manufacturing processes of all three plants are predominately closed systems during the fermentation and recovery process steps. The process equipment is designed to keep microbial contaminants in the ambient environment from getting into the production culture. All growth and holding tanks are closed during process operations. The culture broth is transferred between separate unit operations in the fermentation process step by a steam sterilizable pipe network. Employee contact with the production process, once the raw materials have been added, is minimal other than for equipment maintenance or manual broth sample extraction.

WORK PRACTICES

Each plant maintained a housekeeping program around unit processes -- generally to reduce the possibility of contaminating an enzyme broth that was under production. This housekeeping program also helped to minimize any unnecessary exposures to employees from hazardous agents or conditions. Plant 2 employed a computerized preventive maintenance program as part of their "good" work practice policy. Weekly printouts were provided by the computer detailing the equipment and/or instruments in need of routine maintenance. There was also a regularly scheduled (dependent upon the degree of bearing usage) vibration analysis conducted on all bearings.

SAFETY AND HEALTH PROGRAMS

Plant 1

Plant 1 did not have an environmental health program but was in the process of developing a committee to oversee all health hazard issues (a Health Assurance Committee). Specific health assessments included; audiometric studies, pulmonary studies, sensitivity studies (to enzymes), and environmental sampling methods. The committee was to be composed of personnel from the corporate level and from the production plant (production workers). Additionally, an industrial hygienist and an occupational health physician, outside consultants, were to sit on this committee.

Pre-employment physical examinations were given to all new employees of Plant 1. Subsequent examinations were administered by a state mobile health unit on an annual basis and included audiometric tests and pulmonary function tests. The parent company has conducted tests for enzyme sensitivity among its employees overseas (using a radioallergosorbent test -- RAST). A RAST test was not used at this facility.

The employees played a major role in the development of safety and health guidelines in Plant 1. Using the concept of "quality circles", employees selected safety related projects that they have collectively researched and presented them to management for consideration. The employees initiated the engineering studies needed to evaluate the feasibility of these projects but the studies were actually conducted by the Engineering Department. Employees could also submit project studies that were directly related to process operations. As part of their safety program, Plant 1 has had two safety committees for a number of years. The first committee was composed of randomly selected employee representatives of each department who met once a month. The second committee is composed of management personnel and meets one week after the employee committee meeting to discuss the relevant topics of the employee meeting.

Plant 2

The environmental health program in effect at the time of the survey at Plant 2 was monitored by the Quality Control Manager. Although Plant 2 did not employ a full-time industrial hygienist at the plant, there was a corporate industrial hygienist available on a consulting basis from the parent company. As part of this program, routine workplace concentration monitoring was

conducted for active aerosolized solution enzymes. Samples were taken at six different monitoring locations utilizing a Galley high-volume sampler. All assays were accomplished in-house at the plant laboratory.

Plant 2 implemented a relatively complete medical/biological examination and monitoring program. Pre-screening employee physicals were conducted including a complete allergy battery and interpretation. Blood samples were taken annually from all employees for RAST tests to determine whether antibodies are being produced to specific antigenic compounds to which they may be exposed. Exposure records were maintained for each employee. Annual audiometric tests were conducted in order to monitor employees' hearing ability and to note any changes or deterioration that may occur. Annual physical examinations for employees included urine analysis, pulmonary function tests, chart eye checks, ear checks for wax accumulation, immunization with tetanus toxoid or booster (every 5 years), and a review of the employees' previous physical examination records. A heavy emphasis was placed upon the respiratory evaluation section of the annual physicals. There were no medical practitioners (e.g. doctors, nurses, etc.) on call at the plant during normal working hours, however, two local physicians performed physical examinations and provided emergency medical treatment. In addition, a rescue squad was located 3 miles from the plant complex to the west and a hospital, 6 miles to the east.

Plant 2's safety program and operations were guided by a Safety Committee composed of a chairman and two members, one salaried and one hourly, from each of the following Departments: Maintenance, Manufacturing, Farm, and Laboratory. In addition, a member of the Personnel Department served on the Committee. The chairmanship rotated between departments. This committee conducted monthly meetings and made quarterly safety inspections of all facilities. Quarterly safety lectures for the workers were conducted, and also programs in emergency training and Cardio Pulmonary Resuscitation. Safety problems were considered a priority. All accidents were documented.

Plant 2 also had a spill control procedure. The procedures attempted to address and resolve two problems: one, control of the spill and clean-up of the spilled material, and two, disposal of the spilled material and its effect on the Plant 2 waste treatment system. The procedures included procedures for handling spills pertaining to food grade ingredients or chemicals, salts, bases, acids, oils and refrigerants, and fuel oils. Clean clothes, provided and cleaned by Plant 2, were required everyday. Showers were also required at the end of every work day and lockers were also provided for each employee.

Plant 2 employed a company procedure for entering a deep-tank reactor vessel. These procedures required a second person as an observer, continuous fresh air replenishment inside the tank during the complete operation, a safety harness attached to a mechanical lifting device, and a mechanical/electrical lockout procedure.

Plant 3

The environmental health program for the Plant 3 enzyme operation was monitored on the corporate level. The responsibilities of the Safety and Health and Medical Departments included the entire plant complex and its

employees. As part of the environmental health program, settling plate samples were collected in the enzyme production area. These samples indicated strictly enzyme producing or nonproducing colonies. Plant 3 was attempting to develop a total (quantitative) colony count sampling methodology. They were also attempting to develop a procedure (activity test) for detecting minute quantities of enzyme in the ambient air.

Pre-placement medical evaluations were conducted including a complete medical history, pulmonary function test, audiometric test, visual exam, cardiogram, CBC, urine analysis, and a SMA-14. Periodic medical evaluations are selectively performed. If a problem was encountered with an enzyme production employee, medical treatment was conducted individually on a case-by-case basis, based on the recommendation of the treating physician.

PERSONAL PROTECTIVE EQUIPMENT

Personal protection requirements varied from plant to plant. All of the plants required disposable dust respirators to be worn in all bag emptying processes where the generation of "problem" dusts are suspected. In addition, Plant 2 required the use of additional personal protection devices in applicable areas. Safety glasses were required to be worn at all times unless face shields or goggles are required. Safety shoes are required to be worn at all times except for "walk-throughs." Ear protection is required to be worn while working in the evaporator and utility rooms. Acid goggles, rubber gloves, and aprons are required to be worn while transporting or handling acids and caustics (this requirement is also supported by Plant 3). A respirator (Willson canister type - Type H-3), rubber gloves, and a rain suit are required to be worn whenever a worker is handling formaldehyde. In all plants, self-contained breathing apparatuses are available if needed.

INDIVIDUAL PLANT SAMPLING RESULTS AND DISCUSSION

The individual results of the viable air sampling analysis are reported in the Appendices A, B, and C and summarized in Table 2. Background samples located outside were grouped into a single classification. This classification of outside background level was based on the assumption that uncontrollable environmental factors (e.g., climatic conditions, surrounding traffic, etc.) had the only significant effect upon sample location variability. Effects on outside background samples due to plant unit processes, if any, were assumed to be uniform from sample location to sample location. The results were also assumed to be log normally distributed. All samples were blank corrected.

Quantitative results of the production microorganism were available from Plant 1 and Plant 2. However, quantitative results of the production strain at Plant 3 were available for only part of the survey due to unavoidable circumstances that inhibited microbiological analysis. Viable samples were not collected around certain areas of the recovery process at Plant 1 (mash treatment tank) due to the explosion classification of the area and the fact that the sampling pumps were not intrinsically safe.

TABLE 2. Microorganism Concentrations (mg/m³)

PLANT	SAMPLE LOCATION	N ^a	GEOMETRIC MEAN ^b	GEOMETRIC STD	MINIMUM VALUE	MAXIMUM VALUE
1	Background - inside	12	316	3.6	7	782
1	Background - outside	56	122	7.6	0	1490
1	Clean Room	12	2	5.1	0	73
1	Incubation Room	6	330	1.1	298	382
1	Laboratory	10	150	1.5	91	295
1	Fermentor Agitator	20	337 ^c	3.1	84	2298
1	Seed Agitator	20	1630 ^c	1.5	1057	4230
1	Sample Port	11	348 ^c	3.4	62	2900
1	Scrubber	30	343 ^c	4.2	0	1700
1	Filter Operation	28	5620 ^c	2.5	988	29000
1	Dumpster	9	2400 ^c	1.5	1161	4657
2	Background - inside	49	264	2.0	35	895
2	Background - outside	20	111	3.7	3	638
2	Clean Room	6	2	3.0	0	12
2	Incubation Room	8	171	3.3	32	435
2	Laboratory	6	389	1.7	134	563
2	Fermentor Agitator	38	194	2.3	39	1020
2	Seed Agitator	24	258	1.8	104	766
2	Sample Port	6	646 ^c	1.6	336	983
2	Filter Operation	45	214	2.1	61	2030
3	Background - inside	21	171	3.2	21	875
3	Background - outside	7	49	1.4	32	81
3	Clean Room	6	0	1.0	0	0
3	Incubation Room	2	35	1.8	23	53
3	Laboratory	11	7	3.5	0	34
3	Fermentor Agitator	28	217	2.0	85	620
3	Seed Agitator	30	95	2.3	24	723
3	Sample Port	8	356 ^c	1.5	151	555
3	Filter Operation	32	796 ^c	1.9	357	5860
3	Filter Operation 2	42	873 ^c	2.9	208	6570

a - Number of samples.

b - Colony Forming Units per cubic meter of air (CFU/m³).

c - Statistically higher than appropriate background level at that plant at the 95% confidence level.

The individual results of the enzyme air sampling analysis (for Plant 1) are reported in the Appendix D and summarized in Table 3. All of the samples were blank corrected. Due to complications with the enzyme analytical method for α -amylase, results for Plant 2 and Plant 3 were unavailable. The major complications included a method lacking the desired sensitivity and the degradation of the enzyme molecule caused by the airflow through the filter of the sampling instrument.

Enzyme levels at Plant 1, at all sampling locations, were below the ACGIH recommended Threshold Limit Value (TLV) of 0.8 DU/m³. There appeared to be no statistically significant differences between locations. Data for Plants 2 and 3 were unavailable due to a lack of an analytical method.

TABLE 3. Enzyme Concentrations (DU/m³)

PLANT	SAMPLE LOCATION	N ^a	GEOMETRIC MEAN	GEOMETRIC STD	MINIMUM VALUE	MAXIMUM VALUE
1	Blender Tank	4	0.40	1.74	0.20	0.74
1	Candle Filter	4	0.30	1.46	0.21	0.49
1	Fermentor	3	0.27	2.05	0.16	0.61
1	Ultrafilter	4	0.40	1.73	0.23	0.66

a - Number of samples.

The individual results of the total dust air sampling analysis are reported in the Appendices D and E and summarized in Table 3. All of the samples were blank corrected. Total dust concentrations using the 35 mm cassettes were comparable with the total dust results from the high-volume samplers. Results for both the high-volume and personal sampling pump samples indicate total dust levels well below the ACGIH TLV for nuisance dust of 10 mg/m³.¹⁸

TABLE 4. Total Dust Concentrations (mg/m³)

PLANT	SAMPLE LOCATION	N ^a	GEOMETRIC MEAN	GEOMETRIC STD	MINIMUM VALUE	MAXIMUM VALUE
1	Blender Tank	4	0.10	1.34	0.07	0.14
1	Candle Filter	4	0.13	1.96	0.06	0.37
1	Fermentor	3	0.06	1.13	0.05	0.07
1	Ultrafilter	4	0.14	1.35	0.09	0.21
2	Weigh Station	2	0.14	1.19	0.12	0.17
2	Bag Dump Station	2	0.11	1.00	0.11	0.11
2	Filter Press	4	0.12	1.15	0.10	0.15
2	Aging Tanks	3	0.09	1.50	0.05	0.13
2	Fermentor Tank	3	0.06	1.39	0.04	0.08
3	Drop Tank	4	0.13	3.86	0.04	1.11
3	Outside Bag Dump	4	0.47	1.64	0.24	0.76
3	Rotary Filter	3	0.08	2.22	0.04	0.25
3	Centrifuge	4	0.09	1.62	0.04	0.17
3	Fermentor Tank	4	0.09	2.03	0.05	0.22

a - Number of samples.

Acetone sample results from Plant 1 (at the filter press and the mash treatment tank) are reported in Appendix F. The arithmetic average concentration of all samples was less than 3.6 mg/m³. All samples are blank corrected.

Plant 1

The individual plant results of the air sampling for viable process microorganisms for Plant 1 are summarized in Table 5.

TABLE 5. Plant 1 Microorganism Concentrations (CFU/m³)

SAMPLE LOCATION	N ^a	GEOMETRIC MEAN ^b	GEOMETRIC STD	MINIMUM VALUE	MAXIMUM VALUE
Background - RR tracks	23	54	9.8	0	856
Background - behind office	17	117	7.2	0	1091
Background - cafeteria	3	270	1.3	208	313
Background - meeting room	5	701	1.1	602	782
Background - field	4	700	1.2	572	784
Background - locker room	2	32	7.3	7	134
Background - office	2	528	1.6	371	750
Background - water tower	12	341	2.7	53	1493
Clean Room	12	2	5.1	0	73
Dumpster	9	2398	1.5	1161	4657
Fermentor Agitator Shaft	20	337	3.1	84	2298
Filter Press - closed	17	3904	2.5	988	23588
Filter Press - closing	4	8755	1.4	5320	11601
Filter Press - open	7	10599	1.8	4484	28989
Incubation Room	6	330	1.1	298	382
Main Laboratory	2	145	1.1	137	154
Quality Control Laboratory	8	151	1.6	91	295
Sample Port - closed	8	193	2.3	62	490
Sample Port - open	3	1666	1.6	1215	2902
Scrubber	30	343	4.2	0	1702
Seed Agitator Shaft	20	1632	1.5	1057	4231

a - Number of samples.

b - Colony Forming Units per cubic meter of air (CFU/m³).

Laboratory Process Step--

Emission sources of the production microorganism, Bacillus subtilis (Bs), during the laboratory process step are at very low levels due to the small quantity of the microorganism being used. Emissions in the main laboratory room were observed to exist only during biochemical analysis of broth samples from the seed and fermentor tanks. General work practices of the lab workers constituted the greatest determinant of exposure to viable process microorganisms. For example, mechanical devices were used for pipetting wet solutions and microbial cultures but oral pipetting was also observed during the microbial transfer process in the clean room. The laboratory air quality was controlled via the building heating, ventilation, and air-conditioning (HVAC). Two fume hoods were accessible, and adjacent to one another, in the wet chemistry area of the main laboratory for chemistry work. Viable samples in the main laboratory room indicated a microbial geometric mean level of 147 CFU/m³ with a geometric standard deviation of 1.1. An average of 34 percent of the counted colonies were identified as the production strain, Bs.

Quality control analysis was conducted in a separate analytical laboratory and building from the main laboratory. The geometric mean of the microbial level in the analytical laboratory was 159 CFU/m³ with a geometric standard deviation of 1.6 (35% of the total colony counts were determined to be the production strain). The survey microbiologic analytical team conducted their microbial analysis in this room and their activity and work with the process microorganism may have affected levels.

Possible emissions sites were also observed in the clean room -- during transfer of the Bs cultures from vial to test tube, test tube to flask, and flask to inoculating devices. The clean room contains a horizontal laminar flow hood which purifies recirculated air with a High Efficiency Particulate Air (HEPA) filter. The hood was designed to pass purified air over the work zone, towards the lab technician, to protect the microbial cultures. As a consequence of the airflow directed away from the hood, possible microbial emissions were introduced into the technicians breathing zone. However, the large volume of air recirculated by the hood effectively reduced the concentration of any microbial emissions by diluting the air. The geometric mean of the microbial level in the clean room was 2 CFU/m³ with a geometric standard deviation of 5.1. An average of 76 percent of the counted colonies were identified as the production strain.

Flasks inoculated with the Bs culture are transferred to an incubation room adjacent to the clean room. The incubation room is kept at a constant temperature and humidity for proper propagation of the microbial culture. The flasks (sealed with a cotton gauze stopper) are agitated on a shaker assembly for a specified amount of time. The geometric mean of the microbial level in the incubation room was 330 CFU/m³ with a geometric standard deviation of 1.1. An average of 30 percent of the counted colonies were identified as the production strain.

The microbial culture is manually moved from the laboratory to a seed tank in a sterile, stainless steel inoculating device which serves as containment device during the transfer. The inoculating device is then connected to a steam sealed line on the seed tank and the microbial culture is released into the seed tank. The inoculating device is returned to the laboratory and autoclaved.

Fermentation Process Step--

A potential for release of aerosolized microorganisms and/or enzymes existed at certain sites around the seed and fermentor tanks. These sites included the broth sampling ports, agitator shafts, and scrubber for the tank exhaust gases. Broth sampling at the seed and fermentor tanks was an intermittent operation. The sample port valve was closed and continuously steam sealed when not in use to prevent contamination of the culture broth. The steam seal also appeared to be effective in preventing the escape of viable process microorganisms from the sample port. During sampling, the steam seal was turned off and a shake flask and/or beaker was filled with broth. After sampling, the valve is shut off and the steam flow is increased to clear the valve of remaining contaminants. The prescribed company procedure requires that the steam valve be opened only enough to gently wash any remaining microorganisms into a catch basin. However, the procedure observed during the survey involved a completely opened steam valve which aerosolized any microorganisms remaining in the valve. This resulted in a visible brown haze being released from the sample port. The prescribed company procedure requires that the steam valve be opened only enough to gently were any remaining microorganisms into a catch basin. No engineering controls or protective equipment were used during sampling with the exception of a concrete curb that surrounds the area below the fermentor tank to help contain

spills. The sampling procedure was the same for the seed tank and the fermentor tank. The geometric mean of the microbial level around the sampling port during manual broth sampling was 1666 CFU/m³ with a geometric standard deviation of 1.6 and an average of 77 percent of the colonies identified as the production strain. The geometric mean of the microbial level around the sampling port when there was no external activities was 193 CFU/m³ with a geometric standard deviation of 2.3 and an average of 19 percent of the colonies identified as the production strain. The viable level during manual broth sampling was statistically different from the average outside background levels for the sampling week whereas the microbial level around the sampling port with no external activity was not, indicating the release and viability of production strain Bs during the sampling procedure.

The agitator shaft bearing and seal (packed gland type) at the top of the seed and fermentor tank was continuously steam purged. There is an additional bearing at the bottom of the tank to steady the shaft. Sampling results around the fermentor tank agitator shaft indicated a geometric mean microbial level of 337 CFU/m³ with a geometric standard deviation of 3.1. The percentage of counted colonies identified as the production strain was an average of 48. Sampling results around the seed tank agitator shaft indicated a geometric average microbial level of 1632 CFU/m³ with a geometric standard deviation of 1.5. The percentage of counted colonies identified as the production strain was an average of 23. Both locations had total microbial levels that were statistically different from the average outside background level indicating the possibility of leaks around the agitator shafts.

A water scrubber (located on a platform 30 feet from the fermentor tank agitator shaft) was installed to clean the exhaust gases from the seed and fermentor tanks. Worker activity around the water scrubber was minimal other than for maintenance. Samples collected next to the scrubber showed a geometric mean microbial level of 343 CFU/m³ with a geometric standard deviation of 4.2. The percentage of counted colonies identified as the production strain was an average of 38. This level of total microorganisms was statistically higher than the outside background concentration indicating that the water scrubber was not completely effective in preventing the release of entrained production microorganisms. In situations requiring more stringent controls a more efficient method may be required.

A high-volume air sampler was placed in the vicinity (within 15 feet) of the fermentor tank agitator shaft and the water scrubber. Enzyme geometric mean levels at this location were 0.27 DU/m³ with a geometric standard deviation of 2.05

Broth samples from the mash treatment tank are manually collected from a port in the top of the tank. The tank is opened by the worker and the sample is taken with a dipper cup. Emission sources of the Bs culture, proteolytic enzyme, and acetone could occur during this procedure. The total exposure time of the worker is small. Viable process microorganisms and enzyme air samples could not be taken at this location because the sampling pumps were not intrinsically safe and could not be used in a potentially explosive atmosphere. Acetone samples were less than 0.01 mg/m³.

Recovery Process Step--

After acetone addition in the treatment tank, the microbial/enzyme broth is transferred through a pipe to the automated filter press for an approximate two hour cycle. This cycle will occur many times during the processing of one enzyme fermentation batch. Automation of the filter press does not preclude worker interaction with the process; the worker manually removed (with a wood oar) the filter cake at the end of a cycle. Microbial levels during removal of the filter cake ranged as high as 28990 CFU/m³ on a single sample. Geometric mean microbial levels when the filter press was closed were 3904 CFU/m³ with a geometric standard deviation of 2.5. Geometric mean microbial levels when the filter press was open were 10599 CFU/m³ with a geometric standard deviation of 1.8. Average levels decreased approximately 50% when the filter press was closed. Geometric mean microbial levels when the filter press was closing after the filter cake had been removed were 8755 CFU/m³ with a geometric standard deviation of 1.4. Counts of the production strain on these samples were not made due to time constraints and other analytical factors but the production strain was noted as being the predominant strain at this location by the microbiologist. Geometric mean microbial levels at the dumpster were 2400 CFU/m³ with a geometric standard deviation of 1.5 -- like the filter press, counts of the production strain were not available but were noted as being the predominant organism. Acetone samples collected around the filter press showed one sample at 3.6 mg/m³ and two other samples less than 0.01 mg/m³. Acetone samples collected around the conveyor belt and at the mash treatment tank were all less than 0.01 mg/m³. Enzyme air samples could not be taken in the building that housed the filter press because the sampling pumps were not intrinsically safe and could not be used in a potentially explosive atmosphere. General dilution ventilation was observed in this building including: two ceiling fans, two louvered windows, and one air supply duct on the top floor; and three wall fans, three louvered windows, and one air supply duct on the ground floor.

A local exhaust ventilation hood (with a pulse jet dust collector) was in operation at a dump station in the recovery area for various material additions to the enzyme liquid (diatomaceous earth, calcium carbonate, carbon black, etc.). The hood has a lid with a cylindrical opening into which specially designed bags fit when the lid is down -- effectively enclosing the dumping operation. Unfortunately, the hood was not used by the operator as designed.

The operator, as observed, would normally leave the lid open and pour the raw material directly into the hopper negating the purpose of the "enclosed" system design. The total dust geometric mean concentration at this location was 0.11 mg/m³ with a geometric standard deviation of 11.55. The total dust geometric mean concentration in the recovery room at a location away from the dump station and filter press was 0.08 mg/m³ with a geometric standard deviation of 1.49.

During cleaning and polishing, the acetone-free enzyme liquid is processed through a candle filter. Immediately prior to this operation, filter aids (diatomaceous earth) are manually added to the liquid in a collection tank through a hatch at the top of the tank. Some of the dust generated from this

dumping action was observed passing through the workers' breathing zone on its way to a ceiling fan. Worker interaction after this point is limited to equipment maintenance and enzyme sample extraction. General area geometric mean levels of enzyme were 0.30 DU/m³ with a geometric standard deviation of 1.46 around the candle filter and 0.40 DU/m³ with a geometric standard deviation of 1.74 around the blender tank. High-volume samples were also extracted around the ultrafilters with a geometric mean level of enzyme observed at 0.40 DU/m³ with a geometric standard deviation of 1.73. Only dilution ventilation devices were observed in this area. These included four ceiling fans and two small louvered windows. One high-volume sample was taken outside between the laboratory and the recovery area with a level of 0.27 DU/m³.

Plant 2

The entire facility at Plant 2 was constructed within the last five years and the process design was relatively advanced at that time. The majority of the large-scale process operations are either controlled or monitored by a computer system which is centrally located in a "control room" within the production building. This "automation" aids in limiting direct employee involvement, and therefore potential hazard exposure or contact, with the process operations. The control room was considered a background location and viable samples indicated a geometric mean level of 235 CFU/m³ with a geometric standard deviation of 1.5. The production strain was identified in very low numbers on 3% of the sample plates. The individual plant results of the air sampling for viable process microorganisms for Plant 2 are summarized in Table 6.

TABLE 6. Plant 2 Microorganism Concentrations (CFU/m³)

SAMPLE LOCATION	N ^a	GEOMETRIC MEAN ^b	GEOMETRIC STD	MINIMUM VALUE	MAXIMUM VALUE
Background - filter press	6	270	3.0	35	667
Background - paint shed	14	61	3.0	3	272
Background - paint shed north	6	449	1.5	217	638
Between Aging Tanks	13	343	2.4	89	895
Clean Room	6	2	3.0	0	12
Control Room	30	235	1.5	108	693
Fermentor Agitator Shaft	38	194	2.3	39	1015
Outside incubation room	6	389	1.7	134	563
Incubation Room	8	171	3.3	32	435
Rotary Vacuum Drum Filter	45	214	2.1	61	2028
Sample Port	6	646	1.6	336	983
Seed Agitator Shaft	24	258	1.8	104	766

a - Number of samples.

b - Colony Forming Units per cubic meter of air (CFU/m³).

Laboratory Process Step--

There are possible emission sources of the production microorganism, Bacillus licheniformis (B1), during the laboratory process step but exposures would be at very low levels due to the small quantity of the microorganism being used.

Emissions in the laboratory room were only possible during biochemical analysis of broth samples from the seed and fermentor tanks. There were no bioaerosol samples collected in this area. General work practices of the laboratory workers constituted the greatest determinant of viable emissions. The laboratory air quality was controlled with the building HVAC system. Fume hoods were accessible in the laboratory for wet chemistry work. A biological safety cabinet (equipped with a UV light inside the hood) was available in the room adjacent to the laboratory.

Possible emission sites were also observed in the clean room -- during transfer of the B1 cultures from vial to test tube, test tube to flask, and flask to inoculating devices. The clean room contained a horizontal laminar flow hood which purifies recirculated air with a HEPA filter. The hood is designed to pass purified air over the work zone, towards the lab technician, to protect the microbial cultures. As a consequence of the airflow directed away from the hood, possible process microorganisms were introduced into the technicians breathing zone. However, the large volume of air recirculated by the hood effectively reduces the concentration of any microbial emissions by diluting the air. The geometric microbial level in the clean room was 2 CFU/m³ with a standard deviation of 3.0. The production strain was identified in very low numbers on 33% of the sample plates.

Flasks inoculated with the B1 culture are transferred to an incubation room adjacent to the clean room. The incubation room is kept at a constant temperature and humidity for proper propagation of the microbial culture. The flasks are sealed with a cotton gauze stopper. The geometric mean microbial level in the incubation room was 171 CFU/m³ with a geometric standard deviation of 3.3. The production strain could not be located on any of the sample plates.

The microbial culture was manually moved from the laboratory to the seed tank in a sterile, stainless steel inoculating device which served as a containment device during the transfer. The inoculating device was then connected to a steam sealed line on the seed tank and the microbial culture is released into the seed tank. The inoculating device was returned to the laboratory and autoclaved. It was observed that transfer of the microbial culture from the flask to the inoculating device periodically occurred in the hall outside the clean room. The geometric microbial level in this hallway was 389 CFU/m³ with a geometric standard deviation of 1.7. The production strain could not be located on any of the sample plates.

Fermentation Process Step--

A potential for release of aerosolized process microorganisms and/or enzymes existed at certain sites around the seed and fermentor tanks. These sites included the broth sampling ports, agitator shafts, and exhaust ducts for the seed and fermentor tank off-gases. Broth sampling at the seed and fermentor tanks was an intermittent operation. The sample port valve is closed and continuously steam sealed when not in use to prevent contamination of the culture broth. The steam seal also appeared to be effective in preventing the escape of viables from the sample port. During sampling, the steam seal is turned off and a shake flask and/or beaker is filled with broth. After

sampling, the valve is shut off and the steam is increased to clear the valve of remaining contaminants. The observed position of the steam valve was completely open, which tended to aerosolize any microorganisms remaining in the system. The prescribed company procedure requires that the steam valve be opened only enough to gently wash any remaining microorganisms into a catch basin. No engineering controls or protective equipment were used during sampling. The sampling procedure occurred once per day and was the same for the seed tank and the fermentor tank. The geometric mean microbial level around the sampling port during manual broth sampling was 646 CFU/m³ with a geometric standard deviation of 1.6. The production strain was identified in low quantities on 17% of the sample plates.

The agitator shaft of the seed and fermentor tank is equipped with a double mechanical steam purged seal. Sampling around the fermentor tank agitator shaft indicated a geometric mean microbial level of 194 CFU/m³ with a geometric standard deviation of 2.3. The total dust geometric mean concentration at this location was 0.06 mg/m³ with a standard deviation of 1.39. Sampling around the seed tank agitator shaft indicated a geometric mean microbial level of 258 CFU/m³ with a geometric standard deviation of 1.8. The production strain could not be located on any of the sample plates at these two locations.

The off-gases from the seed and fermentor tanks were ducted to a scrubber and then to an ozone treatment device to eliminate odors. Plant representatives claimed that in addition to the elimination of odors the ozone treatment effectively decontaminated the outgoing air of viable microbes. Viable samples were not collected since an appropriate sampling location was not available.

All bag dumping stations, which included the dumping of raw materials, acids, bases, and diatomaceous earth into their separate container vessels, are controlled with local exhaust ventilation hoods. The ducts for each hood are equipped with manually adjustable dampers which were designed to be closed when the hood is not in use. General work practices of the operators constituted the greatest determinant of exposures. For example, proper company procedure for the disposal of empty bags was to deposit the empty bags into a bag compaction unit which then moves compacted bags into a plastic sack. This sack was then closed with a minimum of exposure to the operator. However, operators neglected to remove and close the sack when the plastic sack became full. Consequently, the sack would fall off of the compaction unit and the compacted bags would then be deposited on the floor. The workers then disposed of the full plastic sack and the compacted bags separately into a dumpster. One bag compaction unit was equipped with local exhaust ventilation. The total dust geometric mean concentration at this location was 0.11 mg/m³ with a geometric standard deviation of 1.00. The total dust geometric mean concentration at a weigh station on the other side of the materials handling room was 0.14 mg/m³ with a geometric standard deviation of 1.19.

Recovery Process Step--

After the fermentation cycle, the microbial/enzyme broth was transferred through a pipe to a holding tank to await concentration and purification. Agitation was maintained in the holding tank but not aeration. The broth was then separated by a rotary vacuum drum filter. The drum filter had a local exhaust ventilation hood on one side which was connected to the main hazard exhaust system. Samples collected around the drum filter indicated a geometric mean microbial concentration of 214 CFU/m³ with a geometric standard deviation of 2.1. This level was compared to a background level across the room next to the aging tanks (geometric average of 343 CFU/m³ with a geometric standard deviation of 2.4) and was not statistically different. The production strain was identified in low quantities on 22% of the sample plates. The total dust level at this location was 0.09 mg/m³ with a standard deviation of 1.50.

The low microbial concentrations around the rotary vacuum drum filter could have a number of possible explanations. First, the stress from the solid-liquid separation of the drum filter may have inactivated the process microorganisms. Second, asphyxiation (caused by the lack of aeration) may have occurred to those cells resident in the holding tank prior to separation. Third, the holding tank is refrigerated which could have affected the viability of the cells. The debilitation or inadvertent destruction of the production microorganisms during separation may be an effective control in reducing emissions. Fourth, the local exhaust hood in combination with the adherence of cells to the vacuum filter effectively minimized the potential emissions. The low level of process microorganisms found may also have resulted from the effective sterilization by steam infusion immediately following separation.

Plant 3

The individual plant results of the air sampling for viable process microorganisms for Plant 3 are summarized in Table 7.

Laboratory Process Step--

Emission sources of the production microorganisms, Bacillus licheniformis (B1), in the laboratory were: the clean room during transfer of the B1 cultures from vial to test tube, test tube to flask, and flask to inoculating devices; and during biochemical analysis of broth samples from the seed and fermentor tanks. The laboratory was on a separate ventilation system from the production area.

The clean room was located in a separate room next to the main laboratory area and the door to the room is kept closed. Workers entering the clean room were required to wear disposable shoe covers. Air samples collected in the clean room did not detect any viable process microorganisms. General area samples taken in the laboratory indicated a geometric mean microbial level of 7 CFU/m³ with a geometric standard deviation of 3.5. This microbial concentration was statistically lower than the plant background concentration location in the drop tank room.

TABLE 7. Plant 3 Microorganism Concentrations (CFU/m³)

SAMPLE LOCATION	N ^a	GEOMETRIC MEAN ^b	GEOMETRIC STD	MINIMUM VALUE	MAXIMUM VALUE
Background - drop tank	21	171	3.2	21	875
Background - laboratory	7	15	2.0	5	34
Background - outside	7	49	1.4	32	81
Background - lab office	4	1	2.7	0	5
Centrifuge	32	796	1.9	357	5855
Clean Room	6	0	1.0	0	0
Fermentor Agitator Shaft	28	217	2.0	85	620
Incubation Room	2	35	1.8	23	53
Rotary Vacuum Belt Filter	42	873	2.9	208	6572
Sample Port	8	356	1.5	151	555
Seed Agitator Shaft	30	95	2.3	24	723

a - Number of samples.

b - Colony Forming Units per cubic meter of air (CFU/m³).

Fermentation Process Step--

A potential for release of aerosolized viable process microorganisms exists at certain sites around the seed and fermentor tanks. These sites include the broth sampling ports and agitator shafts. Broth sampling at the fermentor tanks was an intermittent operation. The sample port valve is closed and continuously steam sealed when not in use to prevent contamination of the culture broth. The steam seal also appeared to be effective in preventing the escape of viables from the sample port. During sampling, the steam seal is turned off and a shake flask and/or beaker is filled with broth. It took approximately 5 seconds to fill a beaker. After sampling, the valve was shut off and the steam flow was increased to bleed the valve of remaining contaminants. A local exhaust hood was attached to the sampling port valve to help reduce emissions during the manual broth sampling. The exhaust hood appeared to capture the bleed stream; but was unable to capture the purge stream. The geometric mean microbial level during manual sampling at the fermentors was 356 CFU/m³ with a geometric standard deviation of 1.5. This microbial level was statistically different from the background concentration inside (drop tank, laboratory, and office) the building. An average of 2 percent of the colonies counted were identified as the production strain.

The agitator shafts for the seed fermentors and the large fermentors have double, mechanical steam-sealed tungsten-against carbon seals. Sample results around the seals of the seed fermentor agitator shaft showed a geometric mean concentration of 95 CFU/m³ with a geometric standard deviation of 2.3. Around the seals of the large fermentor agitator shaft the geometric mean microbial level and the geometric standard deviation was 217 CFU/m³ and 2.0, respectively. This microbial level was statistically higher than the background concentration inside (drop tank, laboratory, and office) the building. An average of 3 percent of the colonies counted were identified as the production strain at the seed fermentor agitator shaft. An average of less than 1 percent of the colonies counted were identified as the production

strain at the large fermentor agitator shaft. Total dust samples, collected next to the fermentor agitator shaft on three days, showed a geometric mean concentration of 0.09 mg/m^3 with a geometric standard deviation of 2.03.

Recovery Process Step--

In process recovery, the product enzyme, α -amylase, was separated from the biomass broth mixture by a rotary vacuum drum filter. The enzyme slurry from the fermentor or drop tank was pumped to the vacuum filter (diatomaceous earth is used as a precoat) where the solids collect on the drum, and the liquid portion (enzyme) was pumped to the concentration process. The solids were removed from the vacuum filter drum by a stellite blade and dropped to a conveyor belt which discharged them to a dumpster. Potential sources for microbial emissions were the vacuum filter itself, the filter solids dropping on the belt, and the conveyor belt. The geometric mean microbial level was 873 CFU/m^3 and the geometric standard deviation was 2.9. This microbial level was statistically higher than the background concentration inside (drop tank, laboratory, and office) the building. Qualitative results showed many of the counted colonies were the production organism at the knife edge and some of the counted colonies were identified as the production organism at the transfer point. Total dust geometric mean concentrations collected near the vacuum filter using the high-volume sampler averaged 0.08 mg/m^3 with a geometric standard deviation of 2.22.

Each centrifuge was equipped with a hood surrounding the centrifuge discharge. The centrifuges were operating while the samples were being collected. The geometric mean microbial level at the centrifuge was 796 CFU/m^3 and the geometric standard deviation was 1.9. This microbial level was statistically higher than the background concentration inside the building. An average of 5 percent of the colonies counted were indentified as the production strain. The total dust geometric mean concentration from samples taken in the centrifuge room was 0.09 mg/m^3 with a geometric standard deviation of 1.62.

All dumping stations for raw materials were equipped with local exhaust ventilation hoods with bag filters built into each exhaust. The hoppers, into which the raw materials were deposited, were equipped with interlocked doors so that the exhaust fans were turned on when the doors were opened. The total dust geometric mean concentration of samples taken outside the door to the dump station room was 0.47 mg/m^3 with a geometric standard deviation of 1.64. High-volume samples for total dust could not be taken in the dump station room because the sample pumps were not intrinsically safe.

COMPARISONS BETWEEN PLANTS

Variations in the microbial concentrations from plant-to-plant were found to be attributed to the type of process equipment utilized, the work practices of the operators, and the microorganism used in production. The results of the microbial sampling at various sites is graphically summarized in Figure 2. Concentrations were highest around filtering operations at two of the plants. At Plant 1, the geometric mean levels of total viable microorganisms at the solid-liquid separation process (filter press as shown in Figure 4) were found to be as high as 5626 CFU/m^3 ; the predominant strain was the production microorganism. At Plant 2, the geometric mean level of total viable

microorganisms at the separation process (rotary vacuum drum filter as shown in Figure 5) equipped with a local exhaust ventilation hood was only as high as 216 CFU/m³; the production strain was identified in very low numbers on only 10 percent of the sample plates. At Plant 3, the geometric mean level of total viable microorganisms at the separation process (centrifuge as shown in Figure 6) ranged as high as 798 CFU/m³; the production strain existed in significant numbers.

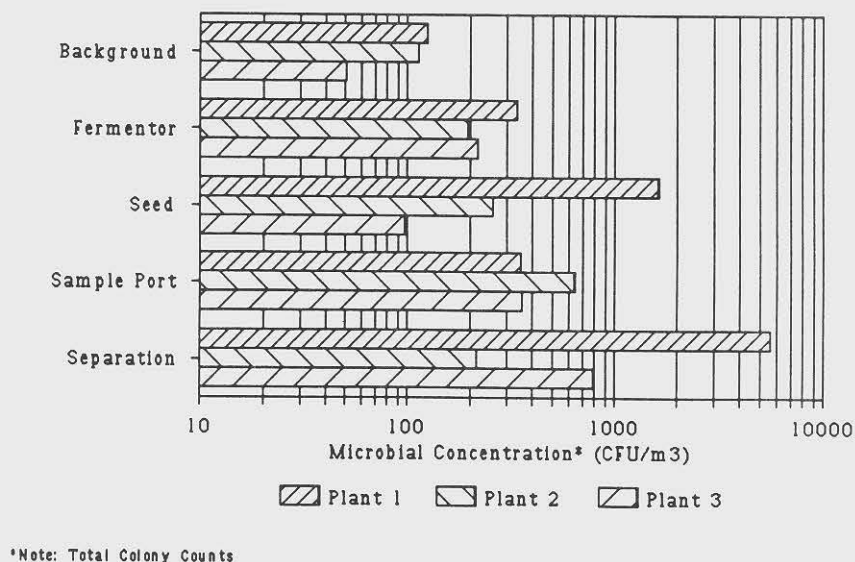


Figure 2. Graphical Summary of Bioaerosol Sampling Results at Specific Process Emission Points

The significantly lower level of microorganisms found during the surveys around the rotary vacuum drum filter in the second plant (Table 8) compared with the levels around the filter press in the first plant seem to be due, in part or combination, to the inherently better containment characteristics of rotary vacuum drum filters, the use of local exhaust ventilation, and the non-viability of the process microorganism. In addition, operator work practices appeared to be a significant factor in determining the higher microbial level during the filter press operation. The operator was observed to remove (with a wooden boat oar) the filter cake that adhered to the filtering elements at the end of the filter press cycle. This was a necessary part of the cycle and a plant authorized procedure. The centrifuge at the third plant would be expected to produce higher microbial emission levels compared to the filter press at the first plant, due to the high velocity rotations of the centrifuge. However, due to the process enclosure and the use of local exhaust ventilation, the microbial emissions that were measured around the centrifuge were at significantly lower levels than the filter press.

Table 8. Tukey's Multiple Range Test Applied To Process Locations

LOCATION	PLANT	N ^a	GEOMETRIC MEAN ^b	GEOMETRIC STD	TUKEY'S TEST ^c
Background	1	56	124	7.6	A
	2	20	113	3.7	A
	3	7	51	1.4	A
Fermentor Agitator	1	20	339	3.1	A
	2	38	196	2.3	A
	3	28	219	2.0	A
Seed Agitator	1	20	1634	1.5	A
	2	24	260	1.6	B
	3	30	97	2.3	C
Sample Port	1	11	350	3.4	A
	2	6	648	1.6	A
	3	8	358	1.5	A
Separation	1	28	5626	2.5	A
	2	45	216	2.1	B
	3	32	798	1.9	C

a - N indicates the number of samples per location.

b - Colony Forming Units per cubic meter of air (CFU/m³).

c - A location which has the same Tukey's grouping (letter) between plants does not differ significantly. Tests for differences between locations are not shown.

In a few cases, increased microorganism concentrations were associated with specific locations around the seed and fermentor tanks (Figure 7). The highest levels occurred around ports that were used to manually sample for the microbial broth mixture inside the seed and fermentor tanks. Local exhaust ventilation at the sampling port of the third plant had little effect on containing microbial emissions. Operator technique during the broth sampling procedure appeared to be the primary determinant of the level of contamination. Operators in all three plants normally purged the sample port with a blast of pressurized steam, which resulted in the aerosolization of any microbial contaminants remaining in the system. A gentle washing of the interior pipes with steam, producing a liquid condensate which could be collected and disposed of, (this was the stated policy of the plants involved) should prove effective in reducing of exposure. Microorganism concentrations at the manual sampling port at the three plants were not significantly different. Sampling data concerning the exhaust gases from the seed and fermentor tanks are limited to the first plant due to the inaccessibility of the exhaust gas ducts in the other two plants. However, the data from plant 1 indicates that the exhaust gases, as expected, could be a source of microbial emissions. The water scrubber from plant 1 showed measurable emissions of entrained viable microorganisms.

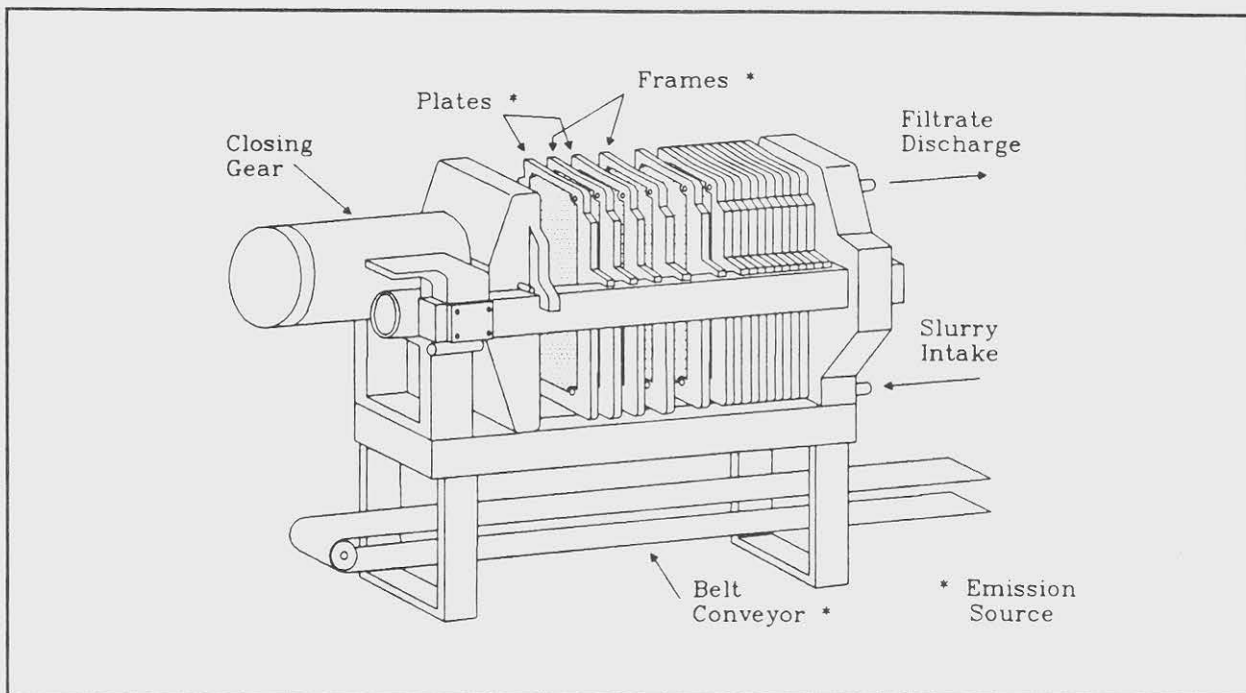


Figure 4. Filter Press (adapted from Reference ³³).

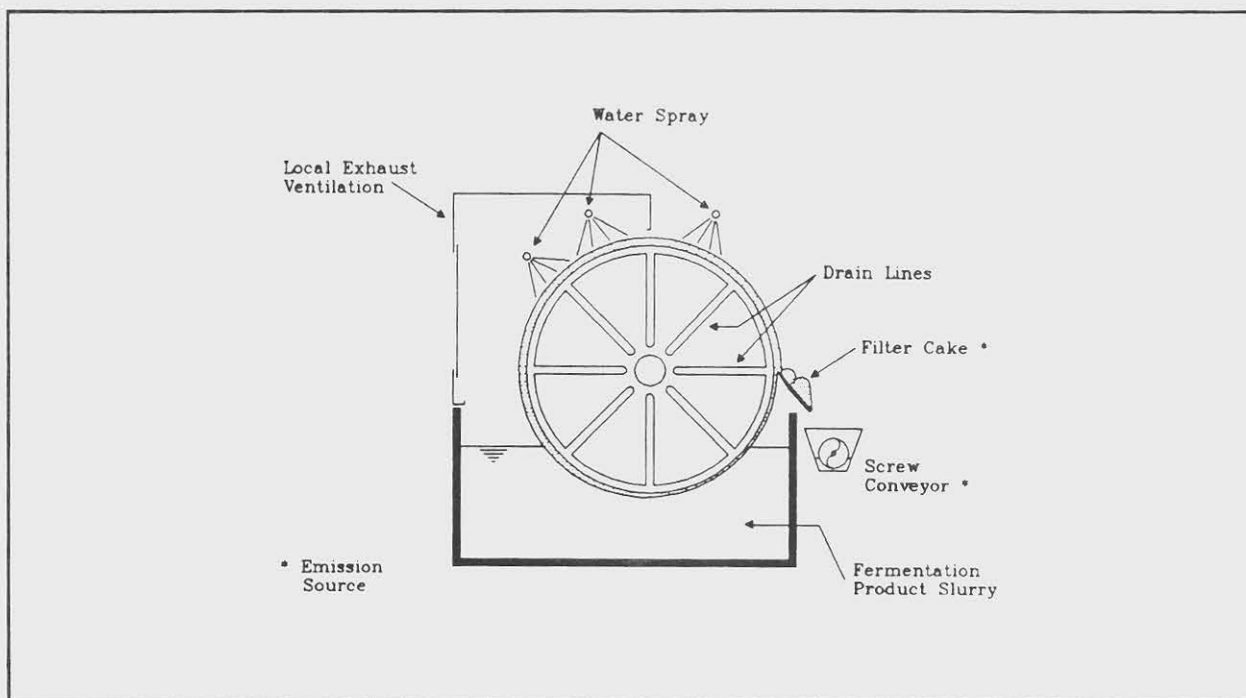


Figure 5. Rotary Vacuum Drum Filter (adapted from Reference ³⁴).

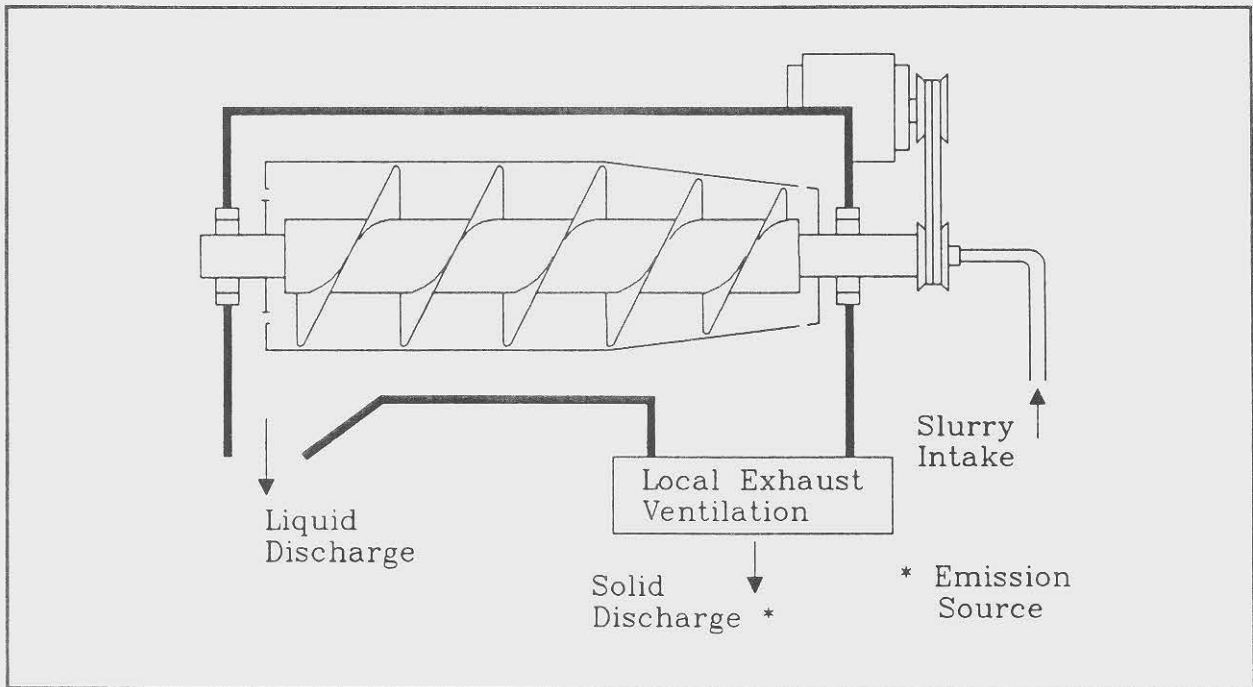


Figure 6. Centrifuge (adapted from Reference ³⁰).

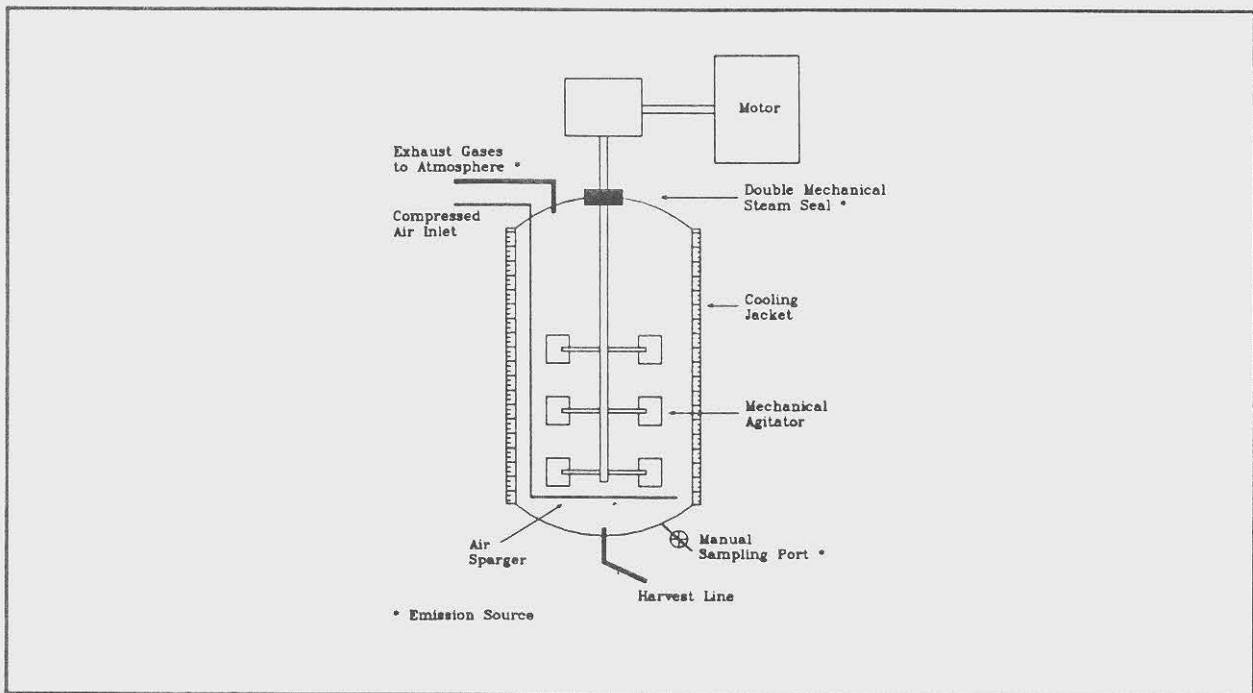


Figure 7. Typical Fermentor Tank

Agitator shafts equipped with double mechanical steam seals appeared to be effective in their ability to contain the microbial culture inside the seed and fermentor tanks, whereas packed seals showed some leakage. Microbial concentrations around the seed agitator shafts were significantly different among the plants surveyed, as were the concentration of production organisms around the fermentor agitator shaft. These differences may be explained by the fact that plant 1 used a packed seal around the seed and fermentor tank agitator shafts, while plants 2 and 3 utilized double mechanical steam seals around all agitator shafts.

Although the design of the processing equipment is an important factor in determining the effective containment of production microorganisms, a debilitated strain can also reduce the viable microbial levels around processing equipment. Plant 1 exhibited higher concentrations of viable microorganisms around a majority of the process sites sampled compared to similar sites at plants 2 and 3. This higher concentration of viable microbes could be partially related to the sporagenic nature of the production strain and the ability of this strain to adapt to conditions outside of the fermentation process. Plants 2 and 3 used asporogenic strains of Bacilli in their process operations. Plant 2 utilized a strain of Bacillus that appeared to exhibit an extremely low tolerance to conditions outside of the fermentation process. The confounding effect of these variables is not known. However, the viable concentrations did correlate well with visual observations of the apparent quality and effectiveness of the engineering controls that were in place.

Variations of the microbial concentrations between plants for other sampling locations were small compared to those near the processing equipment. These locations included the clean room, incubation room, and analytical laboratory. No statistical differences were detected between plant clean rooms (Table 9) and the geometric means did not exceed 5 CFU/m³. Significant differences were detected between plant incubation rooms and analytical laboratories, but these differences involved total microbial colonies and not production strain organisms. The amount of the production strain among these differing plant locations was negligible. Work practices of the technicians in these locations appeared to be the major determining factor affecting the degree of potential microbial exposure. For example, pipetting of any solution by mouth, which was commonly observed, is contrary to safety procedures in any laboratory and should be avoided. These microbial concentrations around the laboratory operations are summarized in Figure 7.

Temperature and humidity effects were tested using a linear regression model fitting least-squares estimates. There appeared to be minor correlations at background locations (inside and outside) of all three plants. However, the effects diminished significantly around unit process locations.

Work practices of the operators can also be a determining factor in the degree of exposure, as in the case of the operator extracting a broth sample from the sampling port. Microbial exposures at filtering operations can be greatly reduced by limiting operator interaction with those processes or, if this is

not possible, the observance of proper and safe work practices. Work practices are most reliable when used in combination with effective engineering measures such as isolation or automation.

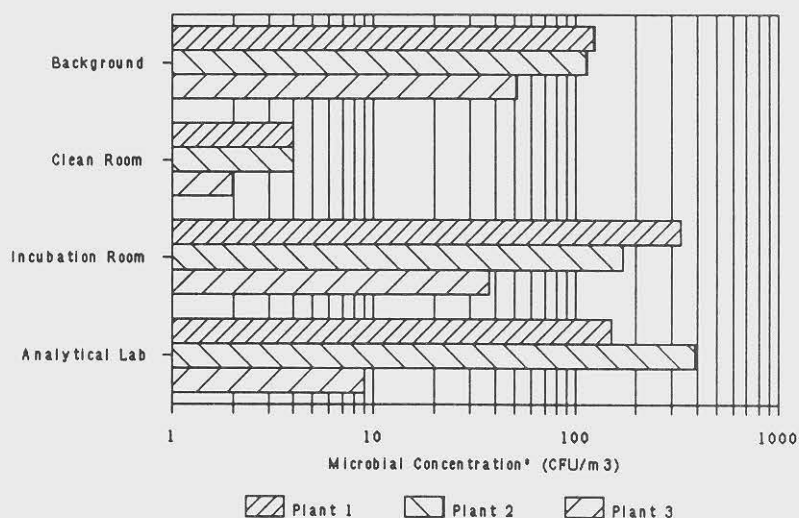
Table 9. Tukey's Multiple Range Test Applied To Other Locations

LOCATION	PLANT	N ^a	GEOMETRIC MEAN ^b	GEOMETRIC STD	TUKEY'S TEST ^c
Clean Room	1	12	4	5.1	A
	2	6	4	3.0	A
	3	6	2	1.0	A
Incubation Room	1	6	332	1.1	A
	2	8	173	3.3	AB
	3	2	37	1.8	B
Analytical Laboratory	1	10	152	1.5	A
	2	6	391	1.7	A
	3	11	9	3.5	B

a - N indicates the number of samples per location.

b - Colony Forming Units per cubic meter of air (CFU/m³).

c - A location which has the same Tukey's grouping (letter) between plants does not differ significantly. Tests for differences between locations are not shown.



*Water Total Colony Counts

Figure 7. Graphical Summary of Sampling Results Around Laboratory Operations

CONCLUSIONS

Viable sample concentrations around selected unit processes were compared (using the pooled t-statistic for comparing two means) to background

concentrations to ascertain the degree of containment of those processes within each plant. This statistical analysis, combined with the identification and quantification of the production strain, helped to pinpoint viable process microorganism emission sites. In addition, the use of Tukey's multiple range test helped assess the effectiveness of various in-place controls. These analyses showed differences among plant processes that can be attributed to the inherent designs of each piece of equipment, the chronological age of each piece of equipment, the use of local exhaust ventilation, and the survivability properties of a particular microorganism strain. The results indicated that controls are most needed around certain high energy operations including filters or centrifuges, agitator shafts, and manual sampling ports (these operations are often not amenable to complete sealing, enclosure or isolation).

Microorganism concentrations were highest around the filtering operations at each of the the plants with the exception of Plant 2. The significantly lower level of microorganisms around the rotary vacuum drum filter at Plant 2 compared with the microorganism levels around the filter press at Plant 1 and the centrifuge at Plant 3 seem to be due to the inherently better containment characteristics of drum filters. Although drum filters, by their design, are open to the surrounding environment, the potential for microbial aerosolization is small because (1) the filter cake adheres to the drum wall via suction, (2) the rotation of the drum is slow, and (3) there is limited operator interaction that would cause disruption of the filter cake. The water spray that wets the filter cake could possibly cause microbial aerosolization but this is offset by the use of local exhaust ventilation. The centrifuge at Plant 3 could be expected to produce higher microbial emission levels due to the high velocity rotations of the separating equipment. However, the engineering design of a centrifuge dictates that it be an enclosed process leaving minimal opportunities (with the exception of the solid discharge point) for the release of the solid/liquid mixture being separated. In fact, hermitically sealed centrifuges are available which virtually eliminate the possibility of microorganism/product emissions.

Generally, where total containment of a potential emission source involving non-pathogens was not a feasible alternative, it was determined that local exhaust ventilation would be an effective means in controlling emission sources (e.g. rotary vacuum drum filter and centrifuge discharge). If potentially harmful organisms are involved, a more reliable containment system would be the recommended control strategy (where the NIH Guidelines are strictly adhered to). This would involve the selection of a processing scheme (e.g., hermetically sealed centrifuges as opposed to the use of manual filter presses) which is consistent with such containment.

Agitator shafts equipped with double mechanical steam seals appeared to be effective in their ability to contain the microbial culture inside the seed and fermentor tanks, whereas packed seals showed some leakage. It was found that exhaust gases from the seed and fermentor tanks are another major emission source of production microorganisms, and should be controlled with an effective filtering system. Water scrubbers probably would not be completely effective for controlling viable emissions from process exhaust gases.

Work practices of the operators were also found to be a determining factor in the degree of exposure, as in the case of the operator extracting a broth sample from the sampling port. In this study, plant procedures appeared to be adequate to minimize worker exposures. However, these procedures can only be effective if training is provided to the worker and management insures that these procedures are practiced. The practice of pipetting any solution by mouth, which was commonly observed, is contrary to safety procedures in any laboratory and should be avoided. Work practices, of course, are most reliable when used in combination with effective engineering measures such as isolation or automation. For example, microbial exposures at filtering operations would be greatly reduced by limiting operator interaction with those processes or, if this is not possible, more caution must be exercised in the use of proper and safe work practices. In the case of exposures at the manual sample port, it would prove more effective to utilize a totally enclosed sampling system that isolates the hazard from the worker.

The microbial levels quantified in this study should serve as a source (database) for comparing the effectiveness of process equipment in other enzyme plants and related fermentation operations. As more microbial data are collected, these results will serve as a critical starting point for evaluating the controls of process equipment. However, if microorganisms classified as potential hazards (whether from an immunological perspective or those microorganisms believed to be pathogens) are used by industry, the effectiveness of the controls evaluated here may very well prove inadequate.

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A P P E N D I C E S

Appendix A. Plant 1 Bioaerosol Sampling Results

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Background - RR tracks	24-Jun	1000	94	53%	10	13	39	33%	137.3	
Background - RR tracks	24-Jun	1001	94	53%	10	26				
Background - RR tracks	24-Jun	1002	93	54%	5	5	5	100%	35.2	
Background - RR tracks	24-Jun	1003	93	54%	5	0				
Background - RR tracks	24-Jun	1006	93	54%	5	2	3	67%	21.1	
Background - RR tracks	24-Jun	1007	93	54%	5	1				
Background - RR tracks	24-Jun	1008	95	52%	2.5	0	0	0%	0.0	
Background - RR tracks	24-Jun	1009	95	52%	2.5	0				
Background - RR tracks	24-Jun	1010	95	52%	5	0	5	0%	35.2	
Background - RR tracks	24-Jun	1011	95	52%	5	5				
Background - RR tracks	24-Jun	1012	95	51%	10	0	0	0%	0.0	
Background - RR tracks	24-Jun	1013	95	51%	10	0				
Background - RR tracks	24-Jun	1014	94	54%	5	0	1	0%	7.0	
Background - RR tracks	24-Jun	1015	94	54%	5	1				
Background - RR tracks	24-Jun	1016	95	52%	5	0	0	0%	0.0	
Background - RR tracks	24-Jun	1017	95	52%	5	0				
Background - RR tracks	24-Jun	1018	94	55%	2.5	0	0	0%	0.0	
Background - RR tracks	24-Jun	1019	94	55%	2.5	0				
Background - RR tracks	24-Jun	1020	94	55%	2.5	2	2	100%	28.2	
Background - RR tracks	24-Jun	1021	94	55%	2.5	0				
Background - RR tracks	24-Jun	1022	93	53%	10	1	11	9%	38.7	
Background - RR tracks	24-Jun	1023	93	53%	10	10				
Background - RR tracks	27-Jun	1300	79	50%	10	38	128	70%	450.7	1
Background - RR tracks	27-Jun	1301	79	50%	10	90				0
Background - RR tracks	27-Jun	1302	79	51%	15	120	260	54%	610.3	1
Background - RR tracks	27-Jun	1303	79	51%	15	140				0
Background - RR tracks	27-Jun	1304	79	51%	10	46	91	49%	320.4	0
Background - RR tracks	27-Jun	1305	79	51%	10	45				0
Background - RR tracks	27-Jun	1306	80	51%	10	49	100	51%	352.1	3
Background - RR tracks	27-Jun	1307	80	51%	10	51				0
Background - RR tracks	27-Jun	1308	80	51%	10	97	222	56%	781.7	0
Background - RR tracks	27-Jun	1309	80	51%	10	125				0
Background - RR tracks	27-Jun	1310	80	51%	10	28	91	69%	320.4	1
Background - RR tracks	27-Jun	1311	80	51%	10	63				0
Background - RR tracks	27-Jun	1312	81	48%	10	10	10	0%	35.2	0
Background - RR tracks	27-Jun	1313	81	48%	10	0				0
Background - RR tracks	27-Jun	1314	82	48%	10	66	195	66%	686.6	9
Background - RR tracks	27-Jun	1315	82	48%	10	129				0
Background - RR tracks	27-Jun	1316	82	47%	10	114	243	53%	855.6	5
Background - RR tracks	27-Jun	1317	82	47%	10	129				0
Background - RR tracks	26-Jun	1116	98	55%	10	13	27	52%	95.1	
Background - RR tracks	26-Jun	1117	98	55%	10	14				
Background - RR tracks	26-Jun	1118	98	55%	5	0	10	100%	70.4	0
Background - RR tracks	26-Jun	1119	98	55%	5	10				0
Background - RR tracks	26-Jun	1120	98	55%	16	57	126	55%	277.3	
Background - RR tracks	26-Jun	1121	98	55%	16	69				

Appendix A. Plant 1 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m3)	PROCESS STRAIN
Background - water tower	27-Jun	1318	82	40%	10	74	151	51%	531.7	5
Background - water tower	27-Jun	1319	82	40%	10	77				1
Background - water tower	27-Jun	1320	82	40%	10	34	76	55%	267.6	3
Background - water tower	27-Jun	1321	82	40%	10	42				5
Background - water tower	27-Jun	1322	82	45%	10	16	30	47%	105.6	5
Background - water tower	27-Jun	1323	82	45%	10	14				1
Background - water tower	27-Jun	1324	82	48%	10	107	169	37%	595.1	71
Background - water tower	27-Jun	1325	82	48%	10	62				34
Background - water tower	27-Jun	1326	82	44%	10	35	88	60%	309.9	5
Background - water tower	27-Jun	1327	82	44%	10	53				0
Background - water tower	27-Jun	1328	82	40%	10	54	137	61%	482.4	0
Background - water tower	27-Jun	1329	82	40%	10	83				5
Background - water tower	27-Jun	1330	82	40%	11	51	192	73%	614.6	6
Background - water tower	27-Jun	1331	82	40%	11	141				0
Background - water tower	27-Jun	1332	80	40%	10	41	108	62%	380.3	5
Background - water tower	27-Jun	1333	80	40%	10	67				1
Background - water tower	27-Jun	1334	79	40%	10	17	26	35%	91.5	1
Background - water tower	27-Jun	1335	79	40%	10	9				0
Background - water tower	27-Jun	1336	79	40%	10	12	15	20%	52.8	0
Background - water tower	27-Jun	1337	79	40%	10	3				0
Background - water tower	27-Jun	1338	79	41%	10	281	424	34%	1493.0	
Background - water tower	27-Jun	1339	79	41%	10	143				
Background - water tower	27-Jun	1340	79	42%	10	216	306	29%	1077.5	
Background - water tower	27-Jun	1341	79	42%	10	90				
Background - behind offices	25-Jun	1050	90	61%	10	40	71	44%	250.0	
Background - behind offices	25-Jun	1051	90	61%	10	31				
Background - behind offices	25-Jun	1052	90	61%	5	1	1	0%	7.0	
Background - behind offices	25-Jun	1053	90	61%	5	0				
Background - behind offices	25-Jun	1054	91		2.5	0	2	100%	28.2	
Background - behind offices	25-Jun	1055	91		2.5	2				
Background - behind offices	25-Jun	1056			5	0	4	100%	28.2	
Background - behind offices	25-Jun	1057			5	4				
Background - behind offices	25-Jun	1058			5	11	12	8%	84.5	
Background - behind offices	25-Jun	1059			5	1				
Background - behind offices	25-Jun	1062			10	28	47	40%	165.5	
Background - behind offices	25-Jun	1063			10	19				
Background - behind offices	25-Jun	1064			5	0	1	100%	7.0	
Background - behind offices	25-Jun	1065			5	1				
Background - behind offices	25-Jun	1066			5	0	0	0%	0.0	
Background - behind offices	25-Jun	1067			5	0				
Background - behind offices	25-Jun	1068			2.5	14	25	44%	352.1	
Background - behind offices	25-Jun	1069			2.5	11				
Background - behind offices	25-Jun	1070	94	54%	5	9	14	36%	98.6	
Background - behind offices	25-Jun	1071	94	54%	5	5				
Background - behind offices	28-Jun	1410	84	50%	10	50	118	58%	415.5	
Background - behind offices	28-Jun	1411	84	50%	10	68				

Appendix A. Plant 1 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m3)	PROCESS STRAIN
Background - behind offices	28-Jun	1412	86	50%	11	43	76	43%	243.3	
Background - behind offices	28-Jun	1413	86	50%	11	33				
Background - behind offices	28-Jun	1414	88	48%	10	82	202	59%	711.3	
Background - behind offices	28-Jun	1415	88	48%	10	120				
Background - behind offices	28-Jun	1416	89	48%	10	47	125	62%	440.1	
Background - behind offices	28-Jun	1417	89	48%	10	78				
Background - behind offices	28-Jun	1418	90	45%	10	113	264	57%	929.6	
Background - behind offices	28-Jun	1419	90	45%	10	151				
Background - behind offices	28-Jun	1420	91	45%	10	76	201	62%	707.7	
Background - behind offices	28-Jun	1421	91	45%	10	125				
Background - behind offices	28-Jun	1424	92	44%	10	114	310	63%	1091.5	
Background - behind offices	28-Jun	1425	92	44%	10	196				
Background - field	28-Jun	1400	76	70%	10	22	222	90%	781.7	
Background - field	28-Jun	1401	76	70%	10	200				
Background - field	28-Jun	1402	77	65%	11	44	245	82%	784.3	
Background - field	28-Jun	1403	77	65%	11	201				
Background - field	28-Jun	1404	79	65%	10	58	194	70%	683.1	
Background - field	28-Jun	1405	79	65%	10	136				
Background - field	28-Jun	1408	81	55%	8	97	130	25%	572.2	
Background - field	28-Jun	1409	81	55%	8	33				
Background - cafeteria	26-Jun	1100	73	50%	10	27	59	54%	207.7	19
Background - cafeteria	26-Jun	1101	73	50%	10	32				14
Background - cafeteria	26-Jun	1102	73	50%	5	23	43	47%	302.8	16
Background - cafeteria	26-Jun	1103	73	50%	5	20				6
Background - cafeteria	26-Jun	1104	73	50%	10	44	89	51%	313.4	10
Background - cafeteria	26-Jun	1105	73	50%	10	45				6
Background - conference room	26-Jun	1106	73	50%	10	53	171	69%	602.1	35
Background - conference room	26-Jun	1107	73	50%	10	118				48
Background - conference room	26-Jun	1108	73	50%	5	40	88	55%	619.7	28
Background - conference room	26-Jun	1109	73	50%	5	48				24
Background - conference room	26-Jun	1110	73	50%	5	59	111	47%	781.7	34
Background - conference room	26-Jun	1111	73	50%	5	52				26
Background - conference room	26-Jun	1112	73	50%	10	109	218	50%	767.6	30
Background - conference room	26-Jun	1113	73	50%	10	109				39
Background - conference room	26-Jun	1114	73	50%	5	58	107	46%	753.5	43
Background - conference room	26-Jun	1115	73	50%	5	49				22
Background - locker room	26-Jun	1124	77	58%	10	0	2	100%	7.0	
Background - locker room	26-Jun	1125	77	58%	10	2				0
Background - locker room	26-Jun	1126	77	58%	5	13	19	32%	133.8	
Background - locker room	26-Jun	1127	77	58%	5	6				
Background - office	26-Jun	1130	75	58%	20	111	211	47%	371.5	0
Background - office	26-Jun	1131	75	58%	20	100				
Background - office	26-Jun	1132	75	58%	10	115	213	46%	750.0	
Background - office	26-Jun	1133	75	58%	10	98				
Filter Press - open	24-Jun	2001	86		4	276	1871	15%	18343.1	
Filter Press - open	24-Jun	2002	86		4	1595				0

Appendix A. Plant 1 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Filter Press - open	24-Jun	2003	86		4	244	959	25%	9439.0	
Filter Press - open	24-Jun	2004	86		4	715				
Filter Press - open	24-Jun	2015	86		3	406	2209	18%	28989.5	
Filter Press - open	24-Jun	2016	86		3	1803				
Filter Press - open	25-Jun	2033			3	150	343	44%	4483.7	101
Filter Press - open	25-Jun	2032			3	193				165
Filter Press - open	25-Jun	2035			3	203	570	36%	7480.3	162
Filter Press - open	25-Jun	2034			3	367				10
Filter Press - open	25-Jun	2055	87		4	287	938	31%	9232.3	
Filter Press - open	25-Jun	2054	87		4	651				
Filter Press - open	25-Jun	2053	87		4	286	985	29%	9656.9	
Filter Press - open	25-Jun	2056	87		4	699				
Filter Press - closing	24-Jun	2005	86		5	1117	1379	19%	10815.7	
Filter Press - closing	24-Jun	2006	86		5	262				
Filter Press - closing	24-Jun	2007	86		5	893	1118	20%	8803.1	
Filter Press - closing	24-Jun	2008	86		5	225				
Filter Press - closing	25-Jun	2036			3	236	407	42%	5320.3	197
Filter Press - closing	25-Jun	2037			3	171				
Filter Press - closing	25-Jun	2038			3	669	884	24%	11601.0	
Filter Press - closing	25-Jun	2039			3	215				
Filter Press - closed	24-Jun	2009	86		4	231	1394	17%	13666.7	
Filter Press - closed	24-Jun	2010	86		4	1163				
Filter Press - closed	24-Jun	2011	86		4	223	597	37%	5876.0	0
Filter Press - closed	24-Jun	2012	86		4	374				
Filter Press - closed	24-Jun	2017	86		4	2221	2406	92%	23588.2	
Filter Press - closed	24-Jun	2018	86		4	185				0
Filter Press - closed	24-Jun	2019	86		4	170	384	44%	3779.5	
Filter Press - closed	24-Jun	2020	86		4	214				
Filter Press - closed	24-Jun	2021	86		4	64	170	38%	1666.7	
Filter Press - closed	24-Jun	2022	86		4	106				
Filter Press - closed	24-Jun	2023	86		4	87	237	37%	2332.7	
Filter Press - closed	24-Jun	2024	86		4	150				
Filter Press - closed	25-Jun	2024.5			4	36	155	77%	1519.6	10
Filter Press - closed	25-Jun	2025			4	119				10
Filter Press - closed	25-Jun	2026			4	69	183	62%	1801.2	26
Filter Press - closed	25-Jun	2027			4	114				16
Filter Press - closed	25-Jun	2028			4	36	112	68%	1098.0	28
Filter Press - closed	25-Jun	2029			4	76				13
Filter Press - closed	25-Jun	2030			4	83	178	53%	1752.0	60
Filter Press - closed	25-Jun	2031			4	95				19
Filter Press - closed	25-Jun	2040			2.5	253	447	43%	7006.3	
Filter Press - closed	25-Jun	2041			2.5	194				
Filter Press - closed	25-Jun	2042			2.5	273	462	41%	7275.6	
Filter Press - closed	25-Jun	2043			2.5	189				
Filter Press - closed	25-Jun	2044			2.5	224	597	62%	9357.4	
Filter Press - closed	25-Jun	2045			2.5	373				

Appendix A. Plant 1 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Filter Press - closed	25-Jun	2046			2.5	183	339	46%	5338.6	
Filter Press - closed	25-Jun	2047			2.5	156				
Filter Press - closed	25-Jun	2048			5	39	126	69%	988.2	
Filter Press - closed	25-Jun	2049			5	87				
Filter Press - closed	25-Jun	2050			5	1069	1136	6%	8944.9	
Filter Press - closed	25-Jun	2051			5	67				
Filter Press - closed	25-Jun	2060	87		4	245	349	30%	3435.0	
Filter Press - closed	25-Jun	2061	87		4	104				
Sample Port - open	24-Jun	3000	86	50	4	100	148	32%	1312.1	89
Sample Port - open	24-Jun	3001	86	50	4	48				42
Sample Port - open	24-Jun	3003	86	50	4	114	139	18%	1215.0	74
Sample Port - open	24-Jun	3002	86	50	4	25				18
Sample Port - open	25-Jun	3034	98		6	190	444	57%	2902.0	
Sample Port - open	25-Jun	3035	98		6	254				
Sample Port - closed	24-Jun	3004	86	50%	4	20	40	50%	354.6	4
Sample Port - closed	24-Jun	3005	86	50%	4	20				0
Sample Port - closed	24-Jun	3006	86	50%	4	27	33	82%	288.5	0
Sample Port - closed	24-Jun	3007	86	50%	4	6				0
Sample Port - closed	24-Jun	3008	86	50%	4	4	21	19%	186.2	1
Sample Port - closed	24-Jun	3009	86	50%	4	17				3
Sample Port - closed	24-Jun	3010	86	50%	4	5	11	45%	96.2	3
Sample Port - closed	24-Jun	3011	86	50%	4	6				5
Sample Port - closed	24-Jun	3012	86	50%	4	5	7	71%	62.1	0
Sample Port - closed	24-Jun	3013	86	50%	4	2				1
Sample Port - closed	24-Jun	3014	86	50%	4	9	9	100%	78.7	0
Sample Port - closed	24-Jun	3015	86	50%	4	0				0
Sample Port - closed	25-Jun	3036	98	0%	11	78	124	37%	442.1	
Sample Port - closed	25-Jun	3037	98	0%	11	46				
Sample Port - closed	25-Jun	3038	98	0%	10	50	125	60%	490.2	
Sample Port - closed	25-Jun	3039	98	0%	10	75				
Incubation Room	25-Jun	3016	84	42%	17	76	160	53%	333.8	
Incubation Room	25-Jun	3017	84	42%	17	84				
Incubation Room	25-Jun	3020	84	42%	20	60	168	64%	297.9	
Incubation Room	25-Jun	3021	84	42%	20	108				
Incubation Room	25-Jun	3026	83	44%	22	122	237	49%	382.0	
Incubation Room	25-Jun	3027	83	44%	22	115				
Incubation Room	25-Jun	3028	83	44%	20	118	178	34%	315.6	
Incubation Room	25-Jun	3029	83	44%	20	60				
Incubation Room	26-Jun	3078	87	0%	20	NA		NA	NA	
Incubation Room	26-Jun	3079	87	0%	20	52				29
Incubation Room	26-Jun	3084	87	0%	20	143	NA	NA	NA	42
Incubation Room	26-Jun	3085	87	0%	20					31
Incubation Room	26-Jun	3076	87	0%	20	102	160	36%	315.0	20
Incubation Room	26-Jun	3077	87	0%	20	58				20
Incubation Room	26-Jun	3082	87	0%	20	107	175	39%	344.5	30
Incubation Room	26-Jun	3083	87	0%	20	68				35

Appendix A. Plant 1 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Clean Room	25-Jun	3018	66	62%	20	2	6	67%	10.5	
Clean Room	25-Jun	3019	66	62%	20	4				
Clean Room	25-Jun	3022	66	54%	9	0	1	100%	3.9	
Clean Room	25-Jun	3023	66	54%	9	1				
Clean Room	25-Jun	3030	67	54%	10	0	0	0%	0.0	
Clean Room	25-Jun	3031	67	54%	10	0				0
Clean Room	25-Jun	3032	67	54%	10	0	4	100%	14.0	0
Clean Room	25-Jun	3033	67	54%	10	4				
Clean Room	26-Jun	3052		0%	21	32	39	18%	72.8	27
Clean Room	26-Jun	3053		0%	21	7				9
Clean Room	26-Jun	3054		0%	16	0	0	0%	0.0	1
Clean Room	26-Jun	3055		0%	16	0				1
Clean Room	26-Jun	3056		0%	20	0	0	0%	0.0	0
Clean Room	26-Jun	3057		0%	20	0				0
Clean Room	26-Jun	3062	70	0%	20	0	0	0%	0.0	1
Clean Room	26-Jun	3063	70	0%	20	0				1
Clean Room	26-Jun	3064	70	0%	20	0	0	0%	0.0	1
Clean Room	26-Jun	3065	70	0%	20	0				1
Clean Room	26-Jun	3066		0%	20	0	0	0%	0.0	1
Clean Room	26-Jun	3067		0%	20	0				1
Clean Room	26-Jun	3068		0%	21	16	19	16%	35.5	2
Clean Room	26-Jun	3069		0%	21	3				1
Clean Room	26-Jun	3072		0%	20	0	0	0%	0.0	1
Clean Room	26-Jun	3073		0%	20	0				1
Main Laboratory	26-Jun	3058		0%	25	21	98	79%	153.7	12
Main Laboratory	26-Jun	3059		0%	25	77				4
Main Laboratory	26-Jun	3060		0%	20	29	70	59%	137.3	15
Main Laboratory	26-Jun	3061		0%	20	41				21
Quality Control Laboratory	27-Jun	1	76	0%	10	26	70	37%	275.6	10
Quality Control Laboratory	27-Jun	2	76	0%	10	44				9
Quality Control Laboratory	27-Jun	3	76	0%	15	27	69	39%	181.1	6
Quality Control Laboratory	27-Jun	4	76	0%	15	42				10
Quality Control Laboratory	27-Jun	5	76	0%	10	15	34	44%	133.9	0
Quality Control Laboratory	27-Jun	6	76	0%	10	19				9
Quality Control Laboratory	27-Jun	7	76	0%	10	15	75	20%	295.3	9
Quality Control Laboratory	27-Jun	8	76	0%	10	60				19
Quality Control Laboratory	27-Jun	9	76	0%	10	11	25	44%	98.4	5
Quality Control Laboratory	27-Jun	10	76	0%	10	14				8
Quality Control Laboratory	27-Jun	11	76	0%	10	10	23	43%	90.6	4
Quality Control Laboratory	27-Jun	12	76	0%	10	13				6
Quality Control Laboratory	27-Jun	13	76	0%	15	14	60	23%	157.5	2
Quality Control Laboratory	27-Jun	14	76	0%	15	46				
Quality Control Laboratory	27-Jun	15	76	0%	10	5	25	20%	98.4	3
Quality Control Laboratory	27-Jun	16	76	0%	10	20				
Dumpster	28-Jun	3612	75	64%	6	281	434	35%	2565.0	
Dumpster	28-Jun	3613	75	64%	6	153				

Appendix A. Plant 1 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Dumpster	28-Jun	3614	75	64%	6	339	501	32%	2919.6	
Dumpster	28-Jun	3615	75	64%	6	162				
Dumpster	28-Jun	3616	75	64%	6	111	177	37%	1161.4	
Dumpster	28-Jun	3617	75	64%	6	66				
Dumpster	28-Jun	3618	78	58%	5	234	352	34%	2496.5	
Dumpster	28-Jun	3619	78	58%	5	118				
Dumpster	28-Jun	3620	78	58%	5	309	508	39%	3552.4	
Dumpster	28-Jun	3621	78	58%	5	199				
Dumpster	28-Jun	3622	78	58%	5	163	262	38%	2063.0	
Dumpster	28-Jun	3623	78	58%	5	99				
Dumpster	28-Jun	3630		0%	5	243	364	33%	2581.6	
Dumpster	28-Jun	3631		0%	5	121				
Dumpster	28-Jun	3632		0%	5	469	666	30%	4657.3	
Dumpster	28-Jun	3633		0%	5	197				
Dumpster	28-Jun	3634		0%	5	106	174	39%	1370.1	
Dumpster	28-Jun	3635		0%	5	68				
Fermentor Tank - agitator shaft	25-Jun	3040	94	52%	2.5	19	95	80%	1328.7	
Fermentor Tank - agitator shaft	25-Jun	3041	94	52%	2.5	76				
Fermentor Tank - agitator shaft	25-Jun	3042	94	52%	2.5	22	64	66%	907.8	
Fermentor Tank - agitator shaft	25-Jun	3043	94	52%	2.5	42				45
Fermentor Tank - agitator shaft	25-Jun	3044	94	52%	2.5	5	11	55%	153.8	9
Fermentor Tank - agitator shaft	25-Jun	3045	94	52%	2.5	6				9
Fermentor Tank - agitator shaft	25-Jun	3046	94	52%	2.5	0	14	100%	198.6	1
Fermentor Tank - agitator shaft	25-Jun	3047	94	52%	2.5	14				13
Fermentor Tank - agitator shaft	25-Jun	3048	94	52%	2.5	3	82	96%	1146.9	4
Fermentor Tank - agitator shaft	25-Jun	3049	94	52%	2.5	79				82
Fermentor Tank - agitator shaft	25-Jun	3050	94	52%	2.5	4	162	98%	2297.9	4
Fermentor Tank - agitator shaft	25-Jun	3051	94	52%	2.5	158				161
Fermentor Tank - agitator shaft	26-Jun	3129	95	48%	5	5	12	42%	83.9	0
Fermentor Tank - agitator shaft	26-Jun	3130	95	48%	5	7				0
Fermentor Tank - agitator shaft	26-Jun	3131	95	48%	5	0	13	0%	92.2	1
Fermentor Tank - agitator shaft	26-Jun	3132	95	48%	5	13				4
Fermentor Tank - agitator shaft	26-Jun	3133	91	54%	5	2	17	12%	118.9	0
Fermentor Tank - agitator shaft	26-Jun	3134	91	54%	5	15				7
Fermentor Tank - agitator shaft	26-Jun	3135	91	54%	5	17	42	40%	297.9	2
Fermentor Tank - agitator shaft	26-Jun	3136	91	54%	5	25				9
Fermentor Tank - agitator shaft	26-Jun	3137	88	59%	2.5	0	6	0%	83.9	0
Fermentor Tank - agitator shaft	26-Jun	3138	88	59%	2.5	6				2
Fermentor Tank - agitator shaft	26-Jun	3139	88	59%	2.5	0	8	0%	113.5	0
Fermentor Tank - agitator shaft	26-Jun	3140	88	59%	2.5	8				4
Fermentor Tank - agitator shaft	26-Jun	3141	89	56%	2.5	26	70	37%	979.0	7
Fermentor Tank - agitator shaft	26-Jun	3142	89	56%	2.5	44				22
Fermentor Tank - agitator shaft	26-Jun	3143	89	56%	2.5	19	55	35%	780.1	22
Fermentor Tank - agitator shaft	26-Jun	3144	89	56%	2.5	36				19
Fermentor Tank - agitator shaft	27-Jun	3500	82	44%	5	26	35	26%	248.2	1
Fermentor Tank - agitator shaft	27-Jun	3501	82	44%	5	9				0

Appendix A. Plant 1 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Fermentor Tank - agitator shaft	27-Jun	3502	82	44%	5	23	43	47%	300.7	5
Fermentor Tank - agitator shaft	27-Jun	3503	82	44%	5	20				0
Fermentor Tank - agitator shaft	27-Jun	3504	82	44%	5	8	22	64%	156.0	0
Fermentor Tank - agitator shaft	27-Jun	3505	82	44%	5	14				0
Fermentor Tank - agitator shaft	27-Jun	3506	82	44%	5	11	15	27%	104.9	2
Fermentor Tank - agitator shaft	27-Jun	3507	82	44%	5	4				0
Fermentor Tank - agitator shaft	27-Jun	3508	86	40%	5	99	222	55%	1574.5	38
Fermentor Tank - agitator shaft	27-Jun	3509	86	40%	5	123				35
Fermentor Tank - agitator shaft	27-Jun	3510	86	40%	5	41	132	69%	923.1	7
Fermentor Tank - agitator shaft	27-Jun	3511	86	40%	5	91				24
Seed Tank - agitator shaft	27-Jun	3400	75	47%	3	146	265	45%	3132.4	51
Seed Tank - agitator shaft	27-Jun	3401	75	47%	3	119				
Seed Tank - agitator shaft	27-Jun	3402	75	47%	3	164	363	55%	4230.8	
Seed Tank - agitator shaft	27-Jun	3403	75	47%	3	199				62
Seed Tank - agitator shaft	27-Jun	3404	74	49%	2.5	74	162	54%	2265.7	28
Seed Tank - agitator shaft	27-Jun	3405	74	49%	2.5	88				19
Seed Tank - agitator shaft	27-Jun	3406	74	49%	2.5	161	231	30%	3276.6	44
Seed Tank - agitator shaft	27-Jun	3407	74	49%	2.5	70				9
Seed Tank - agitator shaft	27-Jun	3408	74	47%	5	128	219	42%	1553.2	77
Seed Tank - agitator shaft	27-Jun	3409	74	47%	5	91				
Seed Tank - agitator shaft	27-Jun	3412	74	47%	5	139	234	41%	1636.4	
Seed Tank - agitator shaft	27-Jun	3413	74	47%	5	95				65
Seed Tank - agitator shaft	27-Jun	3414	74	47%	6	101	195	48%	1152.5	38
Seed Tank - agitator shaft	27-Jun	3415	74	47%	6	94				24
Seed Tank - agitator shaft	27-Jun	3416	74	47%	6	131	211	38%	1229.6	59
Seed Tank - agitator shaft	27-Jun	3417	74	47%	6	80				29
Seed Tank - agitator shaft	27-Jun	3419	76	50%	5	101	149	68%	1056.7	1
Seed Tank - agitator shaft	27-Jun	3420	76	50%	5	48				6
Seed Tank - agitator shaft	27-Jun	3421	76	50%	5	100	173	58%	1209.8	2
Seed Tank - agitator shaft	27-Jun	3422	76	50%	5	73				5
Seed Tank - agitator shaft	27-Jun	3423	74	50%	5	194	242	80%	1716.3	3
Seed Tank - agitator shaft	27-Jun	3424	74	50%	5	48				5
Seed Tank - agitator shaft	27-Jun	3425	74	50%	5	119	190	63%	1328.7	4
Seed Tank - agitator shaft	27-Jun	3426	74	50%	5	71				5
Seed Tank - agitator shaft	27-Jun	3427	73	49%	5	78	149	52%	1056.7	10
Seed Tank - agitator shaft	27-Jun	3428	73	49%	5	71				25
Seed Tank - agitator shaft	27-Jun	3429	73	49%	5	105	155	68%	1083.9	13
Seed Tank - agitator shaft	27-Jun	3430	73	49%	5	50				19
Seed Tank - agitator shaft	27-Jun	3435	77	45%	10	126	467	27%	1656.0	85
Seed Tank - agitator shaft	27-Jun	3436	77	45%	10	341				128
Seed Tank - agitator shaft	27-Jun	3437	77	45%	10	102	331	31%	1157.3	66
Seed Tank - agitator shaft	27-Jun	3438	77	45%	10	229				114
Seed Tank - agitator shaft	27-Jun	3439	76	48%	5	102	179	57%	1269.5	18
Seed Tank - agitator shaft	27-Jun	3440	76	48%	5	77				34
Seed Tank - agitator shaft	27-Jun	3441	76	48%	5	182	264	69%	1846.2	9
Seed Tank - agitator shaft	27-Jun	3442	76	48%	5	82				20

Appendix A. Plant 1 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m3)	PROCESS STRAIN
Seed Tank - agitator shaft	27-Jun	3443	74	50%	5	115	270	43%	1914.9	9
Seed Tank - agitator shaft	27-Jun	3444	74	50%	5	155				55
Seed Tank - agitator shaft	27-Jun	3445	74	50%	5	133	252	53%	1762.2	22
Seed Tank - agitator shaft	27-Jun	3446	74	50%	5	119				37
Scrubber	26-Jun	3101	80	75%	5	43	51	84%	356.6	35
Scrubber	26-Jun	3102	80	75%	5	8				0
Scrubber	26-Jun	3103	80	75%	5	72	77	94%	546.1	45
Scrubber	26-Jun	3104	80	75%	5	5				1
Scrubber	26-Jun	3105		0%	5	24	27	89%	188.8	15
Scrubber	26-Jun	3106		0%	5	3				3
Scrubber	26-Jun	3107		0%	5	8	54	85%	383.0	5
Scrubber	26-Jun	3108		0%	5	46				31
Scrubber	26-Jun	3109	84	65%	5	60	63	95%	446.8	46
Scrubber	26-Jun	3110	84	65%	5	3				0
Scrubber	26-Jun	3111	84	65%	5	43	45	96%	314.7	34
Scrubber	26-Jun	3112	84	65%	5	2				2
Scrubber	26-Jun	3113		0%	2.5	12	12	100%	170.2	2
Scrubber	26-Jun	3114		0%	2.5	0				0
Scrubber	26-Jun	3115		0%	2.5	23	23	100%	321.7	22
Scrubber	26-Jun	3116		0%	2.5	0				0
Scrubber	26-Jun	3117	86	61%	2.5	103	120	86%	1702.1	61
Scrubber	26-Jun	3118	86	61%	2.5	17				5
Scrubber	26-Jun	3119	86	61%	2.5	75	91	82%	1272.7	29
Scrubber	26-Jun	3120	86	61%	2.5	16				1
Scrubber	26-Jun	3121	85	64%	5	37	70	53%	496.5	
Scrubber	26-Jun	3122	85	64%	5	33				1
Scrubber	26-Jun	3123	85	64%	5	31	47	66%	328.7	
Scrubber	26-Jun	3124	85	64%	5	16				
Scrubber	26-Jun	3125	83	76%	5	156	182	86%	1290.8	143
Scrubber	26-Jun	3126	83	76%	5	26				1
Scrubber	26-Jun	3127	83	76%	5	143	168	85%	1174.8	131
Scrubber	26-Jun	3128	83	76%	5	25				8
Scrubber	27-Jun	3512	87	38%	5	24	110	78%	780.1	0
Scrubber	27-Jun	3513	87	38%	5	86				5
Scrubber	27-Jun	3514	87	38%	5	25	97	74%	678.3	4
Scrubber	27-Jun	3515	87	38%	5	72				4
Scrubber	27-Jun	3516	84	40%	5	9	22	59%	156.0	2
Scrubber	27-Jun	3517	84	40%	5	13				1
Scrubber	27-Jun	3518	84	40%	5	0	0	0%	0.0	1
Scrubber	27-Jun	3519	84	40%	5	0				0
Scrubber	27-Jun	3520	84	38%	5	4	27	85%	191.5	0
Scrubber	27-Jun	3521	84	38%	5	23				0
Scrubber	27-Jun	3522	84	38%	5	12	32	63%	223.8	0
Scrubber	27-Jun	3523	84	38%	5	20				0
Scrubber	27-Jun	3524	86	36%	5	9	18	50%	127.7	1
Scrubber	27-Jun	3525	86	36%	5	9				0

Appendix A. Plant 1 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m3)	PROCESS STRAIN
Scrubber	27-Jun	3526	86	36%	5	8	16	50%	111.9	0
Scrubber	27-Jun	3527	86	36%	5	8				0
Scrubber	27-Jun	3528	83	39%	5	31	50	38%	354.6	4
Scrubber	27-Jun	3529	83	39%	5	19				6
Scrubber	27-Jun	3530	83	39%	5	18	33	45%	230.8	2
Scrubber	27-Jun	3531	83	39%	5	15				1
Scrubber	27-Jun	3532	83	39%	5	7	8	13%	56.7	1
Scrubber	27-Jun	3533	83	39%	5	1				1
Scrubber	27-Jun	3534	83	39%	5	14	25	44%	174.8	4
Scrubber	27-Jun	3535	83	39%	5	11				0
Scrubber	28-Jun	3600	68	70%	5	8	211	96%	1496.5	
Scrubber	28-Jun	3601	68	70%	5	203				
Scrubber	28-Jun	3602	68	70%	5	8	205	96%	1433.6	
Scrubber	28-Jun	3603	68	70%	5	197				
Scrubber	28-Jun	3608	71	72%	5	18	215	92%	1524.8	
Scrubber	28-Jun	3609	71	72%	5	197				
Scrubber	28-Jun	3610	71	72%	5	12	209	94%	1461.5	
Scrubber	28-Jun	3611	71	72%	5	197				

Appendix B. Plant 2 Bioaerosol Sampling Results

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Rotary Vacuum Drum Filter	09-Sep	1000	90	69%	20	35	84	58%	148.4	0
Rotary Vacuum Drum Filter	09-Sep	1001	90	69%	20	49				0
Rotary Vacuum Drum Filter	09-Sep	1002	90	69%	20	54	135	60%	236.2	0
Rotary Vacuum Drum Filter	09-Sep	1003	90	69%	20	81				0
Rotary Vacuum Drum Filter	09-Sep	1004	88	78%	15	28	81	65%	190.8	0
Rotary Vacuum Drum Filter	09-Sep	1005	88	78%	15	53				0
Rotary Vacuum Drum Filter	09-Sep	1007	88	78%	15	64	115	44%	268.2	0
Rotary Vacuum Drum Filter	09-Sep	1006	88	78%	15	51				0
Rotary Vacuum Drum Filter	09-Sep	1008	88	72%	10	15	34	56%	120.1	0
Rotary Vacuum Drum Filter	09-Sep	1009	88	72%	10	19				0
Rotary Vacuum Drum Filter	09-Sep	1010	88	72%	10	31	50	39%	174.9	0
Rotary Vacuum Drum Filter	09-Sep	1011	88	72%	10	19				0
Rotary Vacuum Drum Filter	09-Sep	1016	89	72%	10	11	23	52%	81.3	0
Rotary Vacuum Drum Filter	09-Sep	1017	89	72%	10	12				0
Rotary Vacuum Drum Filter	09-Sep	1018	89	72%	10	6	19	68%	66.5	0
Rotary Vacuum Drum Filter	09-Sep	1019	89	72%	10	13				0
Rotary Vacuum Drum Filter	09-Sep	1020	89	72%	10	66	101	35%	356.9	0
Rotary Vacuum Drum Filter	09-Sep	1021	89	72%	10	35				0
Rotary Vacuum Drum Filter	09-Sep	1022	89	72%	10	27	60	55%	209.9	0
Rotary Vacuum Drum Filter	09-Sep	1023	89	72%	10	33				0
Rotary Vacuum Drum Filter	09-Sep	1024	90	57%	10	22	41	46%	144.9	0
Rotary Vacuum Drum Filter	09-Sep	1025	90	57%	10	19				0
Rotary Vacuum Drum Filter	09-Sep	1026	90	57%	10	28	46	39%	160.9	0
Rotary Vacuum Drum Filter	09-Sep	1027	90	57%	10	18				0
Rotary Vacuum Drum Filter	09-Sep	1028	90	60%	10	6	23	74%	81.3	0
Rotary Vacuum Drum Filter	09-Sep	1029	90	60%	10	17				0
Rotary Vacuum Drum Filter	09-Sep	1030	90	60%	10	24	45	47%	157.4	0
Rotary Vacuum Drum Filter	09-Sep	1031	90	60%	10	21				0
Rotary Vacuum Drum Filter	09-Sep	1032	90	60%	10	23	44	48%	155.5	0
Rotary Vacuum Drum Filter	09-Sep	1033	90	60%	10	21				0
Rotary Vacuum Drum Filter	09-Sep	1034	90	60%	10	53	89	40%	311.4	0
Rotary Vacuum Drum Filter	09-Sep	1035	90	60%	10	36				0
Rotary Vacuum Drum Filter	09-Sep	1036	90	60%	10	32	53	40%	187.3	0
Rotary Vacuum Drum Filter	09-Sep	1037	90	60%	10	21				0
Rotary Vacuum Drum Filter	09-Sep	1038	90	60%	10	50	84	40%	293.9	0
Rotary Vacuum Drum Filter	09-Sep	1039	90	60%	10	34				0
Background - paint shed	09-Sep	2000	89	63%	20	32	51	37%	90.1	0
Background - paint shed	09-Sep	2001	89	63%	20	19				0
Background - paint shed	09-Sep	2002	89	63%	20	28	41	32%	72.4	0
Background - paint shed	09-Sep	2003	89	63%	20	13				0
Background - paint shed	09-Sep	2004	88	63%	20	88	101	13%	178.4	0
Background - paint shed	09-Sep	2005	88	63%	20	13				0
Background - paint shed	09-Sep	2006	88	63%	20	20	29	31%	51.2	0
Background - paint shed	09-Sep	2007	88	63%	20	9				0
Background - paint shed	09-Sep	2008	88	63%	15	8	14	43%	33.0	0
Background - paint shed	09-Sep	2009	88	63%	15	6				0

Appendix B. Plant 2 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Background - paint shed	09-Sep	2010	88	63%	15	11	19	42%	44.8	0
Background - paint shed	09-Sep	2011	88	63%	15	8				0
Background - paint shed	09-Sep	2016			10	1	1	0%	3.5	0
Background - paint shed	09-Sep	2017			10	0				0
Background - paint shed	09-Sep	2018			10	5	5	0%	17.7	0
Background - paint shed	09-Sep	2019			10	0				0
Background - paint shed	09-Sep	2020			9	16	16	0%	62.8	0
Background - paint shed	09-Sep	2021			9	0				0
Background - paint shed	09-Sep	2022			9	10	11	9%	43.2	0
Background - paint shed	09-Sep	2023			9	1				0
Sample Port - fermentor tank	10-Sep	2024	82	80%	6	24	115	79%	677.3	0
Sample Port - fermentor tank	10-Sep	2025	82	80%	6	91				0
Sample Port - fermentor tank	10-Sep	2026	82	80%	6	19	64	70%	376.9	0
Sample Port - fermentor tank	10-Sep	2027	82	80%	6	45				0
Sample Port - fermentor tank	10-Sep	2028	82	80%	6	22	57	61%	335.7	0
Sample Port - fermentor tank	10-Sep	2029	82	80%	6	35				0
Sample Port - fermentor tank	10-Sep	2030	82	80%	6	39	164	76%	965.8	1
Sample Port - fermentor tank	10-Sep	2031	82	80%	6	125				0
Sample Port - fermentor tank	10-Sep	2032	82	80%	6	35	167	79%	983.5	0
Sample Port - fermentor tank	10-Sep	2033	82	80%	6	132				0
Sample Port - fermentor tank	10-Sep	2034	82	80%	6	16	152	89%	895.2	0
Sample Port - fermentor tank	10-Sep	2035	82	80%	6	136				0
Control Room	10-Sep	3000	70	58%	20	174	249	30%	439.9	0
Control Room	10-Sep	3001	70	58%	20	75				0
Control Room	10-Sep	3002	70	58%	15	178	261	32%	614.8	0
Control Room	10-Sep	3003	70	58%	15	83				0
Control Room	10-Sep	3004	70	58%	15	203	294	31%	692.6	0
Control Room	10-Sep	3005	70	58%	15	91				0
Control Room	10-Sep	3006	70	58%	15	93	145	36%	341.6	0
Control Room	10-Sep	3007	70	58%	15	52				0
Control Room	10-Sep	3008	70	58%	15	56	84	33%	197.9	0
Control Room	10-Sep	3009	70	58%	15	28				0
Control Room	10-Sep	3012			20	116	166	30%	293.3	0
Control Room	10-Sep	3013			20	50				0
Control Room	10-Sep	3014			15	86	112	23%	263.8	0
Control Room	10-Sep	3015			15	26				0
Control Room	10-Sep	3016			15	58	92	37%	216.7	0
Control Room	10-Sep	3017			15	34				0
Background - paint shed	10-Sep	3020	93	49%	30	114	231	51%	272.1	0
Background - paint shed	10-Sep	3021	93	49%	30	117				0
Background - paint shed	10-Sep	3018	93	49%	15	13	20	35%	47.1	0
Background - paint shed	10-Sep	3019	93	49%	15	7				0
Background - paint shed	10-Sep	3022	93	49%	15	44	70	37%	164.9	0
Background - paint shed	10-Sep	3023	93	49%	15	26				0
Background - paint shed	10-Sep	3024	93	49%	10	28	69	59%	243.8	0
Background - paint shed	10-Sep	3025	93	49%	10	41				0

Appendix B. Plant 2 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m3)	PROCESS STRAIN
Fermentor Agitator Shaft	10-Sep	4000	78	84%	10	24	58	59%	204.9	0
Fermentor Agitator Shaft	10-Sep	4001	78	84%	10	34				0
Fermentor Agitator Shaft	10-Sep	4002	78	84%	10	22	58	62%	204.9	0
Fermentor Agitator Shaft	10-Sep	4003	78	84%	10	36				0
Fermentor Agitator Shaft	10-Sep	4004	78	84%	10	13	42	69%	148.4	0
Fermentor Agitator Shaft	10-Sep	4005	78	84%	10	29				0
Fermentor Agitator Shaft	10-Sep	4006	78	84%	10	31	78	60%	275.6	0
Fermentor Agitator Shaft	10-Sep	4007	78	84%	10	47				0
Fermentor Agitator Shaft	10-Sep	4008	80	80%	10	0	11	100%	38.9	0
Fermentor Agitator Shaft	10-Sep	4009	80	80%	10	11				0
Fermentor Agitator Shaft	10-Sep	4010	80	80%	10	7	20	65%	70.7	0
Fermentor Agitator Shaft	10-Sep	4011	80	80%	10	13				0
Fermentor Agitator Shaft	10-Sep	4012	80	80%	10	25	31	19%	109.5	0
Fermentor Agitator Shaft	10-Sep	4013	80	80%	10	6				0
Fermentor Agitator Shaft	10-Sep	4014	80	80%	10	9	21	57%	74.2	0
Fermentor Agitator Shaft	10-Sep	4015	80	80%	10	12				0
Fermentor Agitator Shaft	10-Sep	4016	80	80%	15	64	90	29%	212.0	0
Fermentor Agitator Shaft	10-Sep	4017	80	80%	15	26				0
Fermentor Agitator Shaft	10-Sep	4018	80	80%	15	18	40	55%	94.2	0
Fermentor Agitator Shaft	10-Sep	4019	80	80%	15	22				0
Fermentor Agitator Shaft	10-Sep	4024	80	84%	10	17	33	48%	116.6	0
Fermentor Agitator Shaft	10-Sep	4025	80	84%	10	16				0
Fermentor Agitator Shaft	10-Sep	4026	80	84%	10	5	28	82%	98.9	0
Fermentor Agitator Shaft	10-Sep	4027	80	84%	10	23				0
Fermentor Agitator Shaft	10-Sep	4028	80	84%	10	28	40	30%	141.3	0
Fermentor Agitator Shaft	10-Sep	4029	80	84%	10	12				0
Fermentor Agitator Shaft	10-Sep	4030	80	84%	10	34	64	47%	226.1	0
Fermentor Agitator Shaft	10-Sep	4031	80	84%	10	30				0
Fermentor Agitator Shaft	10-Sep	4032	86	64%	10	19	45	58%	159.0	0
Fermentor Agitator Shaft	10-Sep	4033	86	64%	10	26				0
Fermentor Agitator Shaft	10-Sep	4034	86	64%	10	3	28	89%	98.9	0
Fermentor Agitator Shaft	10-Sep	4035	86	64%	10	25				0
Fermentor Agitator Shaft	10-Sep	4036	86	64%	15	2	23	91%	54.2	0
Fermentor Agitator Shaft	10-Sep	4037	86	64%	15	21				0
Fermentor Agitator Shaft	10-Sep	4038	86	64%	15	7	31	77%	73.0	0
Fermentor Agitator Shaft	10-Sep	4039	86	64%	15	24				0
Fermentor Agitator Shaft	10-Sep	4040	89	56%	10	64	104	38%	367.5	0
Fermentor Agitator Shaft	10-Sep	4041	89	56%	10	40				0
Fermentor Agitator Shaft	10-Sep	4042	89	56%	10	55	92	40%	325.1	0
Fermentor Agitator Shaft	10-Sep	4043	89	56%	10	37				0
Fermentor Agitator Shaft	10-Sep	4044	89	56%	15	229	431	47%	1015.3	0
Fermentor Agitator Shaft	10-Sep	4045	89	56%	15	202				0
Fermentor Agitator Shaft	10-Sep	4046	89	56%	15	218	393	45%	925.8	0
Fermentor Agitator Shaft	10-Sep	4047	89	56%	15	175				0
Fermentor Agitator Shaft	10-Sep	4048	90	54%	10	71	146	51%	515.9	0
Fermentor Agitator Shaft	10-Sep	4049	90	54%	10	75				0

Appendix B. Plant 2 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m3)	PROCESS STRAIN
Fermentor Agitator Shaft	10-Sep	4050	90	54%	10	188	276	32%	975.3	0
Fermentor Agitator Shaft	10-Sep	4051	90	54%	10	88				0
Fermentor Agitator Shaft	10-Sep	4052	90	54%	12	34	75	55%	220.8	0
Fermentor Agitator Shaft	10-Sep	4053	90	54%	12	41				0
Fermentor Agitator Shaft	10-Sep	4054	90	54%	15	25	65	62%	153.1	0
Fermentor Agitator Shaft	10-Sep	4055	90	54%	15	40				0
Fermentor Agitator Shaft	10-Sep	4060	89	60%	10	10	23	57%	81.3	0
Fermentor Agitator Shaft	10-Sep	4061	89	60%	10	13				0
Fermentor Agitator Shaft	10-Sep	4062	89	60%	10	9	20	55%	70.7	0
Fermentor Agitator Shaft	10-Sep	4063	89	60%	10	11				0
Clean Room	10-Sep	5000	76	48%	15	0	0		0.0	0
Clean Room	10-Sep	5001	76	48%	15	0				0
Clean Room	10-Sep	5002	76	48%	15	0	0		0.0	0
Clean Room	10-Sep	5003	76	48%	15	0				0
Clean Room	10-Sep	5004	76	48%	15	0	0		0.0	0
Clean Room	10-Sep	5005	76	48%	15	0				1
Clean Room	10-Sep	5006	76	48%	15	0				1
Clean Room	10-Sep	5007	76	48%	15					0
Clean Room	10-Sep	7000	72	50%	20	0	2	100%	3.5	0
Clean Room	10-Sep	7001	72	50%	20	2				0
Clean Room	10-Sep	7002	72	50%	20	0	7	100%	12.4	0
Clean Room	10-Sep	7003	72	50%	20	7				0
Clean Room	10-Sep	7004	72	50%	20	1	2	50%	3.5	0
Clean Room	10-Sep	7005	72	50%	20	1				0
Background - paint shed north	11-Sep	c3026	75	79%	15	20	92	78%	216.7	0
Background - paint shed north	11-Sep	c3027	75	79%	15	72				0
Background - paint shed north	11-Sep	c3028	75	79%	15	151	271	44%	638.4	0
Background - paint shed north	11-Sep	c3029	75	79%	15	120				0
Background - paint shed north	11-Sep	c3030	77	72%	15	111	254	56%	598.4	0
Background - paint shed north	11-Sep	c3031	77	72%	15	143				0
Background - paint shed north	11-Sep	c3032	77	72%	15	59	258	77%	607.8	0
Background - paint shed north	11-Sep	c3033	77	72%	15	199				0
Background - paint shed north	11-Sep	c3034	77	72%	15	36	154	77%	362.8	0
Background - paint shed north	11-Sep	c3035	77	72%	15	118				0
Background - paint shed north	11-Sep	c3038	79	68%	20	125	252	50%	445.2	0
Background - paint shed north	11-Sep	c3039	79	68%	20	127				0
Background - purifier filter	11-Sep	c3040	84	70%	15	126	283	55%	666.7	0
Background - purifier filter	11-Sep	c3041	84	70%	15	157				0
Background - purifier filter	11-Sep	c3042	84	70%	15	50	214	77%	504.1	0
Background - purifier filter	11-Sep	c3043	84	70%	15	164				0
Background - purifier filter	11-Sep	c3044	84	70%	15	54	248	78%	584.2	0
Background - purifier filter	11-Sep	c3045	84	70%	15	194				0
Background - purifier filter	11-Sep	c3046	84	70%	15	53	147	64%	346.3	0
Background - purifier filter	11-Sep	c3047	84	70%	15	94				0
Background - purifier filter	11-Sep	c3050	87	58%	15	7	15	53%	35.3	0
Background - purifier filter	11-Sep	c3051	87	58%	15	8				0

Appendix B. Plant 2 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Background - purifier filter	11-Sep	c3054	86	61%	15	22	67	67%	157.8	0
Background - purifier filter	11-Sep	c3055	86	61%	15	45				0
Incubation Room	11-Sep	3060	97	25%	20	17	39	56%	68.9	0
Incubation Room	11-Sep	3061	97	25%	20	22				0
Incubation Room	11-Sep	3062	97	25%	20	4	18	78%	31.8	0
Incubation Room	11-Sep	c3063	97	25%	20	14				0
Incubation Room	11-Sep	c3064	97	25%	20	8	18	56%	31.8	0
Incubation Room	11-Sep	c3065	97	25%	20	10				0
Hall - outside incubation room	11-Sep	3066	74	55%	20	50	76	34%	134.3	0
Hall - outside incubation room	11-Sep	3067	74	55%	20	26				0
Fermentor Agitator Shaft	11-Sep	c4064	84	57%	15	56	194	71%	457.0	0
Fermentor Agitator Shaft	11-Sep	c4065	84	57%	15	138				0
Fermentor Agitator Shaft	11-Sep	c4066	84	57%	15	57	173	67%	407.5	0
Fermentor Agitator Shaft	11-Sep	c4067	84	57%	15	116				0
Fermentor Agitator Shaft	11-Sep	c4068	84	57%	20	50	203	75%	358.7	0
Fermentor Agitator Shaft	11-Sep	c4069	84	57%	20	153				0
Fermentor Agitator Shaft	11-Sep	c4070	84	57%	20	33	191	83%	337.5	0
Fermentor Agitator Shaft	11-Sep	c4071	84	57%	20	158				0
Fermentor Agitator Shaft	11-Sep	c4072	84	57%	20	65	215	70%	379.9	0
Fermentor Agitator Shaft	11-Sep	c4073	84	57%	20	150				0
Fermentor Agitator Shaft	11-Sep	c4074	84	57%	20	49	153	68%	270.3	0
Fermentor Agitator Shaft	11-Sep	c4075	84	57%	20	104				0
Fermentor Agitator Shaft	11-Sep	c4076	84	57%	20	60	204	71%	360.4	0
Fermentor Agitator Shaft	11-Sep	c4077	84	57%	20	144				0
Fermentor Agitator Shaft	11-Sep	c4078	84	57%	20	74	214	65%	378.1	0
Fermentor Agitator Shaft	11-Sep	c4079	84	57%	20	140				0
Fermentor Agitator Shaft	11-Sep	c4080	85	54%	20	34	72	53%	127.2	0
Fermentor Agitator Shaft	11-Sep	c4081	85	54%	20	38				0
Fermentor Agitator Shaft	11-Sep	c4082	85	54%	20	23	61	62%	107.8	0
Fermentor Agitator Shaft	11-Sep	c4083	85	54%	20	38				0
Seed Fermentor	11-Sep	4500	91	68%	15	229	302	24%	711.4	0
Seed Fermentor	11-Sep	4501	91	68%	15	73				0
Seed Fermentor	11-Sep	4502	91	68%	15	254	325	22%	765.6	0
Seed Fermentor	11-Sep	4503	91	68%	15	71				0
Seed Fermentor	11-Sep	4504	91	68%	15	24	79	70%	186.1	0
Seed Fermentor	11-Sep	4505	91	68%	15	55				0
Seed Fermentor	11-Sep	4506	91	68%	15	64	158	59%	372.2	0
Seed Fermentor	11-Sep	4507	91	68%	15	94				0
Seed Fermentor	11-Sep	4512	93	56%	15	27	48	44%	113.1	0
Seed Fermentor	11-Sep	4513	93	56%	15	21				0
Seed Fermentor	11-Sep	4514	93	56%	15	26	50	48%	117.8	0
Seed Fermentor	11-Sep	4515	93	56%	15	24				0
Control Room	11-Sep	c6024	73	70%	15	28	46	39%	108.4	0
Control Room	11-Sep	c6025	73	70%	15	18				0
Control Room	11-Sep	c6026	73	70%	15	29	50	42%	117.8	0
Control Room	11-Sep	c6027	73	70%	15	21				0

Appendix B. Plant 2 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m3)	PROCESS STRAIN
Control Room	11-Sep	c6028	75	64%	20	73	121	40%	213.8	0
Control Room	11-Sep	c6029	75	64%	20	48				0
Control Room	11-Sep	c6030	75	64%	20	59	120	51%	212.0	0
Control Room	11-Sep	c6031	75	64%	20	61				0
Control Room	11-Sep	c6016	71	65%	15	49	59	17%	139.0	0
Control Room	11-Sep	c6017	71	65%	15	10				0
Control Room	11-Sep	c6018	71	65%	15	59	80	26%	188.5	0
Control Room	11-Sep	c6019	71	65%	15	21				0
Control Room	11-Sep	c6008	78	50%	20	98	147	33%	259.7	0
Control Room	11-Sep	c6009	78	50%	20	49				0
Control Room	11-Sep	c6011	78	50%	20	100	184	46%	325.1	0
Control Room	11-Sep	c6010	78	50%	20	84				0
Control Room	11-Sep	c6012	78	50%	15	20	52	62%	122.5	0
Control Room	11-Sep	c6013	78	50%	15	32				0
Control Room	11-Sep	c6014	78	50%	15	33	66	50%	155.5	0
Control Room	11-Sep	c6015	78	50%	15	33				0
Control Room	11-Sep	c6000	74	59%	20	64	124	48%	219.1	0
Control Room	11-Sep	c6001	74	59%	20	60				0
Control Room	11-Sep	c6002	74	59%	20	75	119	37%	210.2	0
Control Room	11-Sep	c6003	74	59%	20	44				0
Control Room	11-Sep	c6004	74	59%	15	61	110	45%	259.1	0
Control Room	11-Sep	c6005	74	59%	15	49				0
Control Room	11-Sep	c6006	74	59%	15	54	144	63%	339.2	0
Control Room	11-Sep	c6007	74	59%	15	90				0
Seed Fermentor	12-Sep	4516	82	70%	15	67	141	52%	332.2	0
Seed Fermentor	12-Sep	4517	82	70%	15	74				0
Seed Fermentor	12-Sep	4518	82	70%	15	36	90	60%	212.0	0
Seed Fermentor	12-Sep	4519	82	70%	15	54				0
Seed Fermentor	12-Sep	4520	82	70%	10	34	89	62%	314.5	0
Seed Fermentor	12-Sep	4521	82	70%	10	55				0
Seed Fermentor	12-Sep	4522	82	70%	10	39	90	57%	318.0	0
Seed Fermentor	12-Sep	4523	82	70%	10	51				0
Seed Fermentor	12-Sep	4534	82	70%	15	52	193	73%	454.7	0
Seed Fermentor	12-Sep	4525	82	70%	15	141				0
Seed Fermentor	12-Sep	4526	82	70%	15	57	187	70%	440.5	0
Seed Fermentor	12-Sep	4527	82	70%	15	130				0
Seed Fermentor	12-Sep	4528	82	70%	15	49	209	77%	492.3	0
Seed Fermentor	12-Sep	4529	82	70%	15	160				0
Seed Fermentor	12-Sep	4530	82	70%	15	65	213	69%	501.8	0
Seed Fermentor	12-Sep	4531	82	70%	15	148				0
Seed Fermentor	12-Sep	4536	82	70%	20	50	141	65%	249.1	0
Seed Fermentor	12-Sep	4537	82	70%	20	91				0
Seed Fermentor	12-Sep	4538	82	70%	20	39	134	71%	236.7	0
Seed Fermentor	12-Sep	4539	82	70%	20	95				0
Seed Fermentor	12-Sep	4540	82	71%	15	23	76	70%	179.0	0
Seed Fermentor	12-Sep	4541	82	71%	15	53				0

Appendix B. Plant 2 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m3)	PROCESS STRAIN
Seed Fermentor	12-Sep	4542	82	71%	15	35	70	50%	164.9	0
Seed Fermentor	12-Sep	4543	82	71%	15	35				0
Seed Fermentor	12-Sep	4544	82	71%	15	21	52	60%	122.5	0
Seed Fermentor	12-Sep	4545	82	71%	15	21				0
Seed Fermentor	12-Sep	4546	83	68%	15	13	44	70%	103.7	0
Seed Fermentor	12-Sep	4547	83	68%	15	31				0
Seed Fermentor	12-Sep	4548	83	68%	20	53	112	53%	197.9	0
Seed Fermentor	12-Sep	4549	83	68%	20	59				0
Seed Fermentor	12-Sep	4550	83	68%	20	34	95	64%	167.8	0
Seed Fermentor	12-Sep	4551	83	68%	20	61				0
Seed Fermentor	12-Sep	4552	83	68%	15	52	112	54%	263.8	0
Seed Fermentor	12-Sep	4553	83	68%	15	60				0
Seed Fermentor	12-Sep	4554	83	68%	15	30	93	68%	219.1	0
Seed Fermentor	12-Sep	4555	83	68%	15	63				0
Rotary Vacuum Drum Filter	12-Sep	1500	78	64%	15	24	57	58%	134.3	0
Rotary Vacuum Drum Filter	12-Sep	1501	78	64%	15	33				0
Rotary Vacuum Drum Filter	12-Sep	1502	78	64%	15	23	28	18%	66.0	0
Rotary Vacuum Drum Filter	12-Sep	1503	78	64%	15	5				0
Rotary Vacuum Drum Filter	12-Sep	1504	78	64%	20	14	84	83%	148.4	0
Rotary Vacuum Drum Filter	12-Sep	1505	78	64%	20	70				0
Rotary Vacuum Drum Filter	12-Sep	1506	78	64%	20	26	94	72%	166.1	0
Rotary Vacuum Drum Filter	12-Sep	1507	78	64%	20	68				0
Rotary Vacuum Drum Filter	12-Sep	1508	78	64%	15	96	215	55%	506.5	0
Rotary Vacuum Drum Filter	12-Sep	1509	78	64%	15	119				0
Rotary Vacuum Drum Filter	12-Sep	1510	80	58%	15	77	165	53%	388.7	0
Rotary Vacuum Drum Filter	12-Sep	1511	80	58%	15	88				0
Rotary Vacuum Drum Filter	12-Sep	1512	80	58%	15	59	205	71%	482.9	1
Rotary Vacuum Drum Filter	12-Sep	1513	80	58%	15	146				0
Rotary Vacuum Drum Filter	12-Sep	1514	80	58%	15	68	238	71%	560.7	0
Rotary Vacuum Drum Filter	12-Sep	1515	80	58%	15	170				0
Rotary Vacuum Drum Filter	12-Sep	1516	80	58%	10	80	207	61%	731.4	0
Rotary Vacuum Drum Filter	12-Sep	1517	80	58%	10	127				0
Rotary Vacuum Drum Filter	12-Sep	1518	80	58%	10	58	177	67%	625.4	0
Rotary Vacuum Drum Filter	12-Sep	1519	80	58%	10	119				0
Rotary Vacuum Drum Filter	12-Sep	1520	80	58%	15	12	56	79%	131.9	0
Rotary Vacuum Drum Filter	12-Sep	1521	80	58%	15	44				0
Rotary Vacuum Drum Filter	12-Sep	1522	80	58%	15	20	63	68%	148.4	0
Rotary Vacuum Drum Filter	12-Sep	1523	80	58%	15	43				0
Rotary Vacuum Drum Filter	12-Sep	1524	80	58%	20	33	55	40%	97.2	0
Rotary Vacuum Drum Filter	12-Sep	1525	80	58%	20	22				0
Rotary Vacuum Drum Filter	12-Sep	1526	80	58%	20	25	45	44%	79.5	0
Rotary Vacuum Drum Filter	12-Sep	1527	80	58%	20	20				0
Rotary Vacuum Drum Filter	12-Sep	1532	81	59%	15	90	125	28%	294.5	10
Rotary Vacuum Drum Filter	12-Sep	1533	81	59%	15	35				0
Rotary Vacuum Drum Filter	12-Sep	1534	81	59%	15	36	64	44%	150.8	3
Rotary Vacuum Drum Filter	12-Sep	1535	81	59%	15	28				0

Appendix B. Plant 2 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m3)	PROCESS STRAIN
Rotary Vacuum Drum Filter	12-Sep	1536	81	59%	15	47	68	31%	160.2	4
Rotary Vacuum Drum Filter	12-Sep	1537	81	59%	15	21				0
Rotary Vacuum Drum Filter	12-Sep	1538	81	59%	15	78	119	34%	280.3	0
Rotary Vacuum Drum Filter	12-Sep	1539	81	59%	15	41				2
Rotary Vacuum Drum Filter	12-Sep	1540	81	59%	15	82	195	58%	459.4	2
Rotary Vacuum Drum Filter	12-Sep	1541	81	59%	15	113				0
Rotary Vacuum Drum Filter	12-Sep	1542	81	59%	15	80	134	40%	315.7	3
Rotary Vacuum Drum Filter	12-Sep	1543	81	59%	15	54				0
Between Aging Tanks	12-Sep	7010	82	52%	15	102	259	61%	610.1	0
Between Aging Tanks	12-Sep	7009	82	52%	15	157				0
Between Aging Tanks	12-Sep	7012	82	52%	15	179	374	52%	881.0	0
Between Aging Tanks	12-Sep	7011	82	52%	15	195				0
Between Aging Tanks	12-Sep	7014	79	62%	15	41	117	65%	275.6	0
Between Aging Tanks	12-Sep	7013	79	62%	15	76				0
Between Aging Tanks	12-Sep	7016	78	65%	15	23	65	65%	153.1	0
Between Aging Tanks	12-Sep	7015	78	65%	15	42				0
Between Aging Tanks	12-Sep	7018	75	71%	24	57	184	69%	276.7	0
Between Aging Tanks	12-Sep	7017	75	71%	24	127				0
Between Aging Tanks	12-Sep	7020	76	67%	15	24	49	51%	115.4	0
Between Aging Tanks	12-Sep	7019	76	67%	15	25				0
Between Aging Tanks	12-Sep	7022	76	64%	15	18	43	58%	101.3	0
Between Aging Tanks	12-Sep	7021	76	64%	15	25				0
Between Aging Tanks	12-Sep	7026	75	70%	15	10	38	74%	89.5	0
Between Aging Tanks	12-Sep	7025	75	70%	15	28				0
Between Aging Tanks	12-Sep	7028	79	62%	15	0	250	100%	588.9	0
Between Aging Tanks	12-Sep	7027	79	62%	15	250				0
Control Room	13-Sep	7500	71	50%	15	51	97	47%	228.5	0
Control Room	13-Sep	7501	71	50%	15	46				0
Control Room	13-Sep	7502	71	50%	15	46	93	51%	219.1	0
Control Room	13-Sep	7503	71	50%	15	47				0
Control Room	13-Sep	7504	71	50%	20	55	100	45%	176.7	0
Control Room	13-Sep	7505	71	50%	20	45				0
Control Room	13-Sep	7506	71	50%	20	56	110	49%	194.3	0
Control Room	13-Sep	7507	71	50%	20	54				0
Control Room	13-Sep	7508	71	50%	15	72	123	41%	289.8	0
Control Room	13-Sep	7509	71	50%	15	51				0
Control Room	13-Sep	7510	71	50%	15	53	100	47%	235.6	0
Control Room	13-Sep	7511	71	50%	15	47				0
Control Room	13-Sep	7516	71	50%	20	76	115	34%	203.2	0
Control Room	13-Sep	7517	71	50%	20	39				0
Control Room	13-Sep	7518	71	50%	20	92	148	38%	261.5	0
Control Room	13-Sep	7519	71	50%	20	56				0
Incubation Room	13-Sep	8100	95	20%	20	36	222	84%	392.2	0
Incubation Room	13-Sep	8101	95	20%	20	186				0
Incubation Room	13-Sep	8104	95	20%	20	27	226	88%	399.3	0
Incubation Room	13-Sep	8105	95	20%	20	199				0

Appendix B. Plant 2 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Incubation Room	13-Sep	8108	95	20%	20	37	246	85%	434.6	0
Incubation Room	13-Sep	8109	95	20%	20	209				0
Incubation Room	13-Sep	8112	95	20%	20	24	207	92%	365.7	0
Incubation Room	13-Sep	8113	95	20%	20	183				0
Incubation Room	13-Sep	8120	69	55%	20	28	224	88%	395.8	0
Incubation Room	13-Sep	8121	69	55%	20	196				0
Hall - outside incubation room	13-Sep	8102	68	53%	15	52	239	78%	563.0	0
Hall - outside incubation room	13-Sep	8103	68	53%	15	187				0
Hall - outside incubation room	13-Sep	8106	68	53%	20	84	284	70%	501.8	0
Hall - outside incubation room	13-Sep	8107	68	53%	20	200				0
Hall - outside incubation room	13-Sep	8114	69	55%	20	62	263	76%	464.7	0
Hall - outside incubation room	13-Sep	8115	69	55%	20	201				0
Hall - outside incubation room	13-Sep	8118	69	55%	20	36	235	85%	415.2	0
Hall - outside incubation room	13-Sep	8119	69	55%	20	199				0
Hall - outside incubation room	13-Sep	8122	69	55%	20	64	267	76%	471.7	0
Hall - outside incubation room	13-Sep	8123	69	55%	20	203				0
Between Aging Tanks	13-Sep	7029	70	53%	15	102	178	43%	419.3	0
Between Aging Tanks	13-Sep	7030	70	53%	15	76				0
Between Aging Tanks	13-Sep	7031	72	50%	15	145	335	57%	789.2	0
Between Aging Tanks	13-Sep	7032	72	50%	15	190				0
Between Aging Tanks	13-Sep	7033	71	50%	15	148	329	55%	775.0	0
Between Aging Tanks	13-Sep	7034	71	50%	15	181				0
Between Aging Tanks	13-Sep	7035	72	50%	15	179	380	53%	895.2	0
Between Aging Tanks	13-Sep	7036	72	50%	15	201				0
Rotary Vacuum Drum Filter	13-Sep	1544	73	66%	15	150	247	39%	581.9	1
Rotary Vacuum Drum Filter	13-Sep	1545	73	66%	15	97				0
Rotary Vacuum Drum Filter	13-Sep	1546	73	66%	15	654	861	24%	2028.3	0
Rotary Vacuum Drum Filter	13-Sep	1547	73	66%	15	207				0
Rotary Vacuum Drum Filter	13-Sep	1548	73	66%	20	193	335	42%	591.9	1
Rotary Vacuum Drum Filter	13-Sep	1549	73	66%	20	142				0
Rotary Vacuum Drum Filter	13-Sep	1550	73	66%	20					0
Rotary Vacuum Drum Filter	13-Sep	1551	73	66%	20	115				0
Rotary Vacuum Drum Filter	13-Sep	1552	73	66%	15	47	115	59%	270.9	2
Rotary Vacuum Drum Filter	13-Sep	1553	73	66%	15	68				0
Rotary Vacuum Drum Filter	13-Sep	1554	73	66%	15	43	109	61%	256.8	0
Rotary Vacuum Drum Filter	13-Sep	1555	73	66%	15	66				0
Rotary Vacuum Drum Filter	13-Sep	1556	73	66%	15	7	26	73%	61.2	1
Rotary Vacuum Drum Filter	13-Sep	1557	73	66%	15	19				0
Rotary Vacuum Drum Filter	13-Sep	1558	73	66%	15	11	34	68%	80.1	0
Rotary Vacuum Drum Filter	13-Sep	1559	73	66%	15	23				1

Appendix C. Plant 3 Bioaerosol Sampling Results

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m3)	PROCESS STRAIN
Fermentor Sample Port	18-Nov	1000	82	52%	15	39	64	39%	150.8	1
Fermentor Sample Port	18-Nov	1001	82	52%	15	25				
Fermentor Sample Port	18-Nov	1002	82	52%	15	43	103	58%	242.6	2
Fermentor Sample Port	18-Nov	1003	82	52%	15	60				7
Fermentor Sample Port	18-Nov	1028	82	52%	15	152	199	24%	468.8	
Fermentor Sample Port	18-Nov	1029	82	52%	15	47				
Fermentor Sample Port	18-Nov	1030	82	52%	15	102	143	29%	336.9	
Fermentor Sample Port	18-Nov	1031	82	52%	15	41				
Fermentor Agitator Shaft	18-Nov	1004	99	48%	15	29	64	55%	150.8	
Fermentor Agitator Shaft	18-Nov	1005	99	48%	15	35				
Fermentor Agitator Shaft	18-Nov	1006	99	48%	15	14	41	66%	96.6	
Fermentor Agitator Shaft	18-Nov	1007	99	48%	15	27				
Fermentor Agitator Shaft	18-Nov	1008	99	48%	15	12	37	68%	87.2	
Fermentor Agitator Shaft	18-Nov	1009	99	48%	15	25				
Fermentor Agitator Shaft	18-Nov	1010	99	48%	15	30	52	42%	122.5	
Fermentor Agitator Shaft	18-Nov	1011	99	48%	15	22				
Fermentor Agitator Shaft	18-Nov	1012	98	50%	15	69	150	54%	353.4	1
Fermentor Agitator Shaft	18-Nov	1013	98	50%	15	81				1
Fermentor Agitator Shaft	18-Nov	1014	98	50%	15	124	210	41%	494.7	1
Fermentor Agitator Shaft	18-Nov	1015	98	50%	15	86				1
Fermentor Agitator Shaft	18-Nov	1016	98	50%	15	40	72	44%	169.6	
Fermentor Agitator Shaft	18-Nov	1017	98	50%	15	32				
Fermentor Agitator Shaft	18-Nov	1018	98	50%	15	48	89	46%	209.7	
Fermentor Agitator Shaft	18-Nov	1019	98	50%	15	41				
Fermentor Agitator Shaft	18-Nov	1020	98	50%	15	18	37	51%	87.2	
Fermentor Agitator Shaft	18-Nov	1021	98	50%	15	19				
Fermentor Agitator Shaft	18-Nov	1022	98	50%	15	18	43	58%	101.3	
Fermentor Agitator Shaft	18-Nov	1023	98	50%	15	25				0
Fermentor Agitator Shaft	18-Nov	1024	98	50%	15	15	61	75%	143.7	
Fermentor Agitator Shaft	18-Nov	1025	98	50%	15	46				
Fermentor Agitator Shaft	18-Nov	1026	98	50%	15	25	74	66%	174.3	
Fermentor Agitator Shaft	18-Nov	1027	98	50%	15	49				
Fermentor Agitator Shaft	18-Nov	1032	100	50%	15	23	36	36%	84.8	
Fermentor Agitator Shaft	18-Nov	1033	100	50%	15	13				0
Fermentor Agitator Shaft	18-Nov	1034	100	50%	15	22	36	39%	84.8	
Fermentor Agitator Shaft	18-Nov	1035	100	50%	15	14				1
Fermentor Agitator Shaft	18-Nov	1040	100	50%	15	16	48	67%	113.1	
Fermentor Agitator Shaft	18-Nov	1041	100	50%	15	32				1
Fermentor Agitator Shaft	18-Nov	1042	100	50%	15	15	48	69%	113.1	1
Fermentor Agitator Shaft	18-Nov	1043	100	50%	15	33				
Background - next to incubation	18-Nov	2000	75	61%	20	2	2	0%	3.5	
Background - next to incubation	18-Nov	2001	75	61%	20	0				1
Background - next to incubation	18-Nov	2002	72	66%	20	0	0		0.0	
Background - next to incubation	18-Nov	2003	72	66%	20	0				
Background - next to incubation	18-Nov	2004	70	72%	20	3	3	0%	5.3	
Background - next to incubation	18-Nov	2005	70	72%	20	0				

Appendix C. Plant 3 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Background - next to incubation	18-Nov	2008	70	68%	20	0	0		0.0	
Background - next to incubation	18-Nov	2009	70	68%	20	0				
Incubation Room	19-Nov	2010	73	64%	20	6	13	54%	23.0	
Incubation Room	19-Nov	2011	73	64%	20	7				
Incubation Room	19-Nov	2014	75	64%	20	18	30	40%	53.0	
Incubation Room	19-Nov	2015	75	64%	20	12				
Background - laboratory	19-Nov	2016	74	64%	20	9	19	53%	33.6	
Background - laboratory	19-Nov	2017	74	64%	20	10				
Background - laboratory	19-Nov	2020	74	64%	20	6	15	60%	26.5	
Background - laboratory	19-Nov	2021	74	64%	20	9				
Background - drop tank	19-Nov	2500	81	52%	15	53	202	74%	475.9	
Background - drop tank	19-Nov	2501	81	52%	15	149				
Background - drop tank	19-Nov	2502	81	52%	15	3	28	89%	66.0	
Background - drop tank	19-Nov	2503	81	52%	15	25				
Background - drop tank	19-Nov	2504	79	58%	15	7	21	67%	49.5	
Background - drop tank	19-Nov	2505	79	58%	15	14				
Background - drop tank	19-Nov	2508	81	52%	15	4	20	80%	47.1	
Background - drop tank	19-Nov	2509	81	52%	15	16				
Background - drop tank	19-Nov	2510	81	52%	15	5	9	44%	21.2	
Background - drop tank	19-Nov	2511	81	52%	15	4				
Background - drop tank	19-Nov	2514	82	51%	15	6	10	40%	23.6	
Background - drop tank	19-Nov	2515	82	51%	15	4				
Background - 2nd floor	19-Nov	2700	65	79%	20	11	21	48%	37.1	
Background - 2nd floor	19-Nov	2701	65	79%	20	10				
Background - 2nd floor	19-Nov	2702	65	79%	20	9	18	50%	31.8	
Background - 2nd floor	19-Nov	2703	65	79%	20	9				
Background - 2nd floor	19-Nov	2704	65	79%	20	4	24	83%	42.4	
Background - 2nd floor	19-Nov	2705	65	79%	20	20				
Background - 2nd floor	19-Nov	2706	64	79%	20	13	24	46%	42.4	
Background - 2nd floor	19-Nov	2707	64	79%	20	11				
Seed Agitator Shaft	19-Nov	3000	80	62%	15	52	117	56%	275.6	
Seed Agitator Shaft	19-Nov	3001	80	62%	15	65				7
Seed Agitator Shaft	19-Nov	3002	80	62%	15	55	124	56%	292.1	4
Seed Agitator Shaft	19-Nov	3003	80	62%	15	69				13
Seed Agitator Shaft	19-Nov	3004	80	62%	15	9	29	69%	68.3	1
Seed Agitator Shaft	19-Nov	3005	80	62%	15	20				13
Seed Agitator Shaft	19-Nov	3006	80	62%	15	10	28	64%	66.0	
Seed Agitator Shaft	19-Nov	3007	80	62%	15	18				5
Seed Agitator Shaft	19-Nov	3008	87	56%	15	22	39	44%	91.9	
Seed Agitator Shaft	19-Nov	3009	87	56%	15	17				
Seed Agitator Shaft	19-Nov	3010	87	56%	15	16	35	54%	82.4	
Seed Agitator Shaft	19-Nov	3011	87	56%	15	19				
Seed Agitator Shaft	19-Nov	3012	83	74%	15	25	61	59%	143.7	
Seed Agitator Shaft	19-Nov	3013	83	74%	15	36				
Seed Agitator Shaft	19-Nov	3014	83	74%	15	16	59	73%	139.0	
Seed Agitator Shaft	19-Nov	3015	83	74%	15	43				

Appendix C. Plant 3 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Seed Agitator Shaft	19-Nov	3016	86	58%	15	128	300	57%	706.7	
Seed Agitator Shaft	19-Nov	3017	86	58%	15	172				
Seed Agitator Shaft	19-Nov	3018	86	58%	15	127	307	59%	723.2	
Seed Agitator Shaft	19-Nov	3019	86	58%	15	180				
Seed Agitator Shaft	19-Nov	3020	84	63%	15	23	89	74%	209.7	
Seed Agitator Shaft	19-Nov	3021	84	63%	15	66				
Seed Agitator Shaft	19-Nov	3022	84	63%	15	35	94	63%	221.4	
Seed Agitator Shaft	19-Nov	3023	84	63%	15	59				
Seed Agitator Shaft	19-Nov	3028	88	58%	15	23	65	65%	153.1	
Seed Agitator Shaft	19-Nov	3029	88	58%	15	42				
Seed Agitator Shaft	19-Nov	3030	88	58%	15	16	50	68%	117.8	
Seed Agitator Shaft	19-Nov	3031	88	58%	15	34				
Seed Agitator Shaft	19-Nov	3032	87	58%	15	14	31	55%	73.0	2
Seed Agitator Shaft	19-Nov	3033	87	58%	15	17				
Seed Agitator Shaft	19-Nov	3034	87	58%	15	17	44	61%	103.7	2
Seed Agitator Shaft	19-Nov	3035	87	58%	15	27				
Seed Agitator Shaft	19-Nov	3036	84	66%	15	17	30	43%	70.7	
Seed Agitator Shaft	19-Nov	3037	84	66%	15	13				
Seed Agitator Shaft	19-Nov	3038	84	66%	15	12	32	63%	75.4	
Seed Agitator Shaft	19-Nov	3039	84	66%	15	20				
Seed Agitator Shaft	19-Nov	3040	82	70%	15	1	10	90%	23.6	
Seed Agitator Shaft	19-Nov	3041	82	70%	15	9				
Seed Agitator Shaft	19-Nov	3042	82	70%	15	13	29	55%	68.3	
Seed Agitator Shaft	19-Nov	3043	82	70%	15	16				
Seed Agitator Shaft	19-Nov	3044	85	62%	15	18	26	31%	61.2	
Seed Agitator Shaft	19-Nov	3045	85	62%	15	8				
Seed Agitator Shaft	19-Nov	3046	85	62%	15	9	15	40%	35.3	
Seed Agitator Shaft	19-Nov	3047	85	62%	15	6				
Seed Agitator Shaft	19-Nov	3048	86	58%	15	16	26	38%	61.2	
Seed Agitator Shaft	19-Nov	3049	86	58%	15	10				
Seed Agitator Shaft	19-Nov	3050	86	58%	15	17	20	15%	47.1	
Seed Agitator Shaft	19-Nov	3051	86	58%	15	3				
Seed Agitator Shaft	19-Nov	3052	85	64%	15	8	14	43%	33.0	
Seed Agitator Shaft	19-Nov	3053	85	64%	15	6				
Seed Agitator Shaft	19-Nov	3054	85	64%	15	6	11	45%	25.9	
Seed Agitator Shaft	19-Nov	3055	85	64%	15	5				
Seed Agitator Shaft	19-Nov	3060	86	61%	15	8	27	70%	63.6	
Seed Agitator Shaft	19-Nov	3061	86	61%	15	19				
Seed Agitator Shaft	19-Nov	3062	86	61%	15	11	29	62%	68.3	
Seed Agitator Shaft	19-Nov	3063	86	61%	15	18				
Seed Agitator Shaft	19-Nov	3064	87	68%	15	16	31	48%	73.0	
Seed Agitator Shaft	19-Nov	3065	87	68%	15	15				0
Seed Agitator Shaft	19-Nov	3066	87	68%	15	17	31	45%	73.0	
Seed Agitator Shaft	19-Nov	3067	87	68%	15	14				0
Centrifuge	19-Nov	6000	77	80%	10	198	577	66%	2038.9	
Centrifuge	19-Nov	6001	77	80%	10	379				

Appendix C. Plant 3 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Centrifuge	19-Nov	6002	77	80%	10	162	372	56%	1314.5	
Centrifuge	19-Nov	6003	77	80%	10	210				
Centrifuge	19-Nov	6004	81	60%	10	106	243	56%	858.7	
Centrifuge	19-Nov	6005	81	60%	10	137				5
Centrifuge	19-Nov	6006	81	60%	10	104	249	58%	879.9	50
Centrifuge	19-Nov	6007	81	60%	10	145				7
Centrifuge	19-Nov	6010	80	62%	10	56	112	50%	395.8	3
Centrifuge	19-Nov	6011	80	62%	10	56				8
Centrifuge	19-Nov	6008	80	62%	10	71	144	51%	508.8	11
Centrifuge	19-Nov	6009	80	62%	10	73				
Centrifuge	19-Nov	6012	79	65%	10	66	125	47%	441.7	
Centrifuge	19-Nov	6013	79	65%	10	59				
Centrifuge	19-Nov	6014	79	65%	10	132	207	36%	731.4	7
Centrifuge	19-Nov	6015	79	65%	10	75				
Centrifuge	19-Nov	6016	79	62%	10	74	156	53%	551.2	4
Centrifuge	19-Nov	6017	79	62%	10	82				1
Centrifuge	19-Nov	6018	79	62%	10	87	146	40%	515.9	2
Centrifuge	19-Nov	6019	79	62%	10	59				
Background - laboratory	20-Nov	2022	69	41%	20	17	18	6%	31.8	
Background - laboratory	20-Nov	2023	69	41%	20	1				
Background - laboratory	20-Nov	2024	69	41%	20	5	9	44%	15.9	
Background - laboratory	20-Nov	2025	69	41%	20	4				
Background - laboratory	20-Nov	2026	72	37%	20	4	4	0%	7.1	
Background - laboratory	20-Nov	2027	72	37%	20	0				
Background - laboratory	20-Nov	2030	71	32%	20	2	5	60%	8.8	
Background - laboratory	20-Nov	2031	71	32%	20	3				
Background - laboratory	20-Nov	2032	71	32%	20	3	3	0%	5.3	
Background - laboratory	20-Nov	2033	71	32%	20	0				
Background - 2nd floor	20-Nov	2710	28	35%	20	28	37	24%	65.4	
Background - 2nd floor	20-Nov	2711	28	35%	20	9				
Background - 2nd floor	20-Nov	2712	28	35%	20	24	46	48%	81.3	
Background - 2nd floor	20-Nov	2713	28	35%	20	22				
Background - 2nd floor	20-Nov	2714	32	34%	20	15	32	53%	56.5	
Background - 2nd floor	20-Nov	2715	32	34%	20	17				
Rotary Vacuum Belt Filter	20-Nov	6500	66	35%	15	2703	2790	3%	6572.4	
Rotary Vacuum Belt Filter	20-Nov	6501	66	35%	15	87				
Rotary Vacuum Belt Filter	20-Nov	6502	66	35%	15	97	151	36%	355.7	
Rotary Vacuum Belt Filter	20-Nov	6503	66	35%	15	54				
Rotary Vacuum Belt Filter	20-Nov	6504	67	32%	15	1551	1635	5%	3851.6	
Rotary Vacuum Belt Filter	20-Nov	6505	67	32%	15	84				
Rotary Vacuum Belt Filter	20-Nov	6506	67	32%	15	84	145	42%	341.6	
Rotary Vacuum Belt Filter	20-Nov	6507	67	32%	15	61				
Rotary Vacuum Belt Filter	20-Nov	6508	67	32%	15	1263	1335	5%	3144.9	
Rotary Vacuum Belt Filter	20-Nov	6509	67	32%	15	72				
Rotary Vacuum Belt Filter	20-Nov	6510	67	32%	15	88	133	34%	313.3	
Rotary Vacuum Belt Filter	20-Nov	6511	67	32%	15	45				

Appendix C. Plant 3 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Rotary Vacuum Belt Filter	20-Nov	6512	67	32%	15	1247	1333	6%	3140.2	
Rotary Vacuum Belt Filter	20-Nov	6513	67	32%	15	86				
Rotary Vacuum Belt Filter	20-Nov	6514	67	32%	15	96	143	33%	336.9	
Rotary Vacuum Belt Filter	20-Nov	6515	67	32%	15	47				
Rotary Vacuum Belt Filter	20-Nov	6516	67	32%	15	607	693	12%	1632.5	
Rotary Vacuum Belt Filter	20-Nov	6517	67	32%	15	86				
Rotary Vacuum Belt Filter	20-Nov	6518	67	32%	15	87	127	31%	299.2	
Rotary Vacuum Belt Filter	20-Nov	6519	67	32%	15	40				
Rotary Vacuum Belt Filter	20-Nov	6520	68	30%	15	751	877	14%	2066.0	
Rotary Vacuum Belt Filter	20-Nov	6521	68	30%	15	126				
Rotary Vacuum Belt Filter	20-Nov	6522	68	30%	15	109	152	28%	358.1	
Rotary Vacuum Belt Filter	20-Nov	6523	68	30%	15	43				
Rotary Vacuum Belt Filter	20-Nov	6524	69	31%	15	863	926	7%	2181.4	
Rotary Vacuum Belt Filter	20-Nov	6525	69	31%	15	63				
Rotary Vacuum Belt Filter	20-Nov	6526	69	31%	15	112	169	34%	398.1	
Rotary Vacuum Belt Filter	20-Nov	6527	69	31%	15	57				
Rotary Vacuum Belt Filter	20-Nov	6528	68	33%	15	943	1020	8%	2402.8	
Rotary Vacuum Belt Filter	20-Nov	6529	68	33%	15	77				
Rotary Vacuum Belt Filter	20-Nov	6530	68	33%	15	87	131	34%	308.6	
Rotary Vacuum Belt Filter	20-Nov	6531	68	33%	15	44				
Rotary Vacuum Belt Filter	20-Nov	6532	69	31%	15	927	1006	8%	2369.8	
Rotary Vacuum Belt Filter	20-Nov	6533	69	31%	15	79				
Rotary Vacuum Belt Filter	20-Nov	6534	69	31%	15	89	128	30%	301.5	
Rotary Vacuum Belt Filter	20-Nov	6535	69	31%	15	39				
Clean Room	20-Nov	2400	74	32%	20	0	0		0.0	
Clean Room	20-Nov	2401	74	32%	20	0				
Clean Room	20-Nov	2402	74	32%	20	0	0		0.0	
Clean Room	20-Nov	2403	74	32%	20	0				
Clean Room	20-Nov	2406	74	32%	20	0	0		0.0	
Clean Room	20-Nov	2407	74	32%	20	0				
Clean Room	20-Nov	2408	74	32%	20	0	0		0.0	
Clean Room	20-Nov	2409	74	32%	20	0				
Clean Room	20-Nov	2412	74	32%	20	0	0		0.0	
Clean Room	20-Nov	2413	74	32%	20	0				
Clean Room	20-Nov	2414	74	32%	20	0	0		0.0	
Clean Room	20-Nov	2415	74	32%	20	0				
Centrifuge	20-Nov	6024	67	36%	10	101	298	66%	1053.0	
Centrifuge	20-Nov	6025	67	36%	10	197				
Centrifuge	20-Nov	6026	67	36%	10	124	273	55%	964.7	
Centrifuge	20-Nov	6027	67	36%	10	149				
Centrifuge	20-Nov	6028	69	34%	10	92	223	59%	788.0	
Centrifuge	20-Nov	6029	69	34%	10	131				
Centrifuge	20-Nov	6030	69	34%	10	103	201	49%	710.2	
Centrifuge	20-Nov	6031	69	34%	10	98				
Centrifuge	20-Nov	6032	68	33%	10	453	748	39%	2643.1	
Centrifuge	20-Nov	6033	68	33%	10	295				

Appendix C. Plant 3 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Centrifuge	20-Nov	6034	68	33%	10	1455	1657	12%	5855.1	
Centrifuge	20-Nov	6035	68	33%	10	202				
Centrifuge	20-Nov	6036	67	39%	10	262	462	43%	1632.5	
Centrifuge	20-Nov	6037	67	39%	10	200				
Centrifuge	20-Nov	6038	67	39%	10	251	428	41%	1512.4	
Centrifuge	20-Nov	6039	67	39%	10	177				
Centrifuge	20-Nov	6040	68	40%	10	100	183	45%	646.6	
Centrifuge	20-Nov	6041	68	40%	10	83				
Centrifuge	20-Nov	6042	68	40%	10	98	152	36%	537.1	
Centrifuge	20-Nov	6043	68	40%	10	54				
Centrifuge	20-Nov	6044	68	40%	10	90	128	30%	452.3	
Centrifuge	20-Nov	6045	68	34%	10	38				
Centrifuge	20-Nov	6046	68	34%	10	73	101	28%	356.9	
Centrifuge	20-Nov	6047	68	34%	10	28				
Centrifuge	20-Nov	6048	67	40%	10	90	153	41%	540.6	
Centrifuge	20-Nov	6049	67	40%	10	63				
Centrifuge	20-Nov	6050	67	40%	10	99	159	38%	561.8	
Centrifuge	20-Nov	6051	67	40%	10	60				
Centrifuge	20-Nov	6052	67	36%	10	69	125	45%	441.7	
Centrifuge	20-Nov	6053	67	36%	10	56				
Centrifuge	20-Nov	6054	67	36%	10	86	126	32%	445.2	
Centrifuge	20-Nov	6055	67	36%	10	40				
Centrifuge	20-Nov	6056	68	32%	10	197	326	40%	1151.9	
Centrifuge	20-Nov	6057	68	32%	10	129				
Centrifuge	20-Nov	6058	68	32%	10	212	365	42%	1289.8	
Centrifuge	20-Nov	6059	68	32%	10	153				
Centrifuge	20-Nov	6060	70	35%	10	84	155	46%	547.7	
Centrifuge	20-Nov	6061	70	35%	10	71				
Centrifuge	20-Nov	6062	70	35%	10	72	133	46%	470.0	
Centrifuge	20-Nov	6063	70	35%	10	61				
Centrifuge	20-Nov	6064	70	35%	10	121	179	32%	632.5	
Centrifuge	20-Nov	6065	70	35%	10	58				
Centrifuge	20-Nov	6066	70	35%	10	83	287	71%	1014.1	
Centrifuge	20-Nov	6067	70	35%	10	204				
Background - drop tank	21-Nov	2600	73	34%	20	113	142	20%	250.9	
Background - drop tank	21-Nov	2601	73	34%	20	29				
Background - drop tank	21-Nov	2602	73	34%	20	247	495	50%	874.6	
Background - drop tank	21-Nov	2603	73	34%	20	248				
Background - drop tank	21-Nov	2606	73	31%	20	60	291	79%	514.1	
Background - drop tank	21-Nov	2607	73	31%	20	231				
Background - drop tank	21-Nov	2608	72	24%	20	88	201	56%	355.1	
Background - drop tank	21-Nov	2609	72	24%	20	113				
Background - drop tank	21-Nov	2610	72	24%	20	266	446	40%	788.0	
Background - drop tank	21-Nov	2611	72	24%	20	180				
Background - drop tank	21-Nov	2612	74	26%	20	258	399	35%	704.9	
Background - drop tank	21-Nov	2613	74	26%	20	141				

Appendix C. Plant 3 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Background - drop tank	21-Nov	2616	77	31%	20	220	302	27%	533.6	
Background - drop tank	21-Nov	2617	77	31%	20	82				
Background - drop tank	21-Nov	2618	79	25%	20	208	407	49%	719.1	
Background - drop tank	21-Nov	2619	79	25%	20	199				
Background - drop tank	21-Nov	2620	79	25%	20	62	98	37%	173.1	
Background - drop tank	21-Nov	2621	79	25%	20	36				
Background - drop tank	21-Nov	2622	80	20%	20	55	97	43%	171.4	
Background - drop tank	21-Nov	2623	80	20%	20	42				
Background - drop tank	21-Nov	2624	80	20%	20	53	72	26%	127.2	
Background - drop tank	21-Nov	2625	80	20%	20	19				
Background - drop tank	21-Nov	2628	79	22%	20	49	62	21%	109.5	
Background - drop tank	21-Nov	2629	79	22%	20	13				
Background - drop tank	21-Nov	2630	79	22%	20	39	57	32%	100.7	
Background - drop tank	21-Nov	2631	79	22%	20	18				
Background - drop tank	21-Nov	2632	79	22%	20	30	41	27%	72.4	
Background - drop tank	21-Nov	2633	79	22%	20	11				
Background - drop tank	21-Nov	2634	79	22%	20	32	42	24%	74.2	
Background - drop tank	21-Nov	2635	79	22%	20	10				
Fermentor Sample Port	21-Nov	6548	80	21%	10	106	137	23%	484.1	
Fermentor Sample Port	21-Nov	6549	80	21%	10	31				
Fermentor Sample Port	21-Nov	6550	80	21%	10	115	157	27%	554.8	
Fermentor Sample Port	21-Nov	6551	80	21%	10	42				
Fermentor Sample Port	21-Nov	6580	77	21%	10	86	118	27%	417.0	
Fermentor Sample Port	21-Nov	6581	77	21%	10	32				
Fermentor Sample Port	21-Nov	6582	77	21%	10	75	112	33%	395.8	
Fermentor Sample Port	21-Nov	6583	77	21%	10	37				
Fermentor Agitator Shaft	21-Nov	6540	85	42%	15	105	200	48%	471.1	
Fermentor Agitator Shaft	21-Nov	6541	85	42%	15	95				
Fermentor Agitator Shaft	21-Nov	6542	85	42%	15	111	166	33%	391.0	
Fermentor Agitator Shaft	21-Nov	6543	85	42%	15	55				
Fermentor Agitator Shaft	21-Nov	6544	90	40%	15	89	156	43%	367.5	
Fermentor Agitator Shaft	21-Nov	6545	90	40%	15	67				
Fermentor Agitator Shaft	21-Nov	6546	90	40%	15	77	110	30%	259.1	
Fermentor Agitator Shaft	21-Nov	6547	90	40%	15	33				
Fermentor Agitator Shaft	21-Nov	6552	92	46%	15	82	148	45%	348.6	
Fermentor Agitator Shaft	21-Nov	6553	92	46%	15	66				
Fermentor Agitator Shaft	21-Nov	6554	92	46%	15	101	163	38%	384.0	
Fermentor Agitator Shaft	21-Nov	6555	92	46%	15	62				
Fermentor Agitator Shaft	21-Nov	6556	93	42%	15	180	263	32%	619.6	
Fermentor Agitator Shaft	21-Nov	6557	93	42%	15	83				
Fermentor Agitator Shaft	21-Nov	6558	93	42%	15	157	230	32%	541.8	
Fermentor Agitator Shaft	21-Nov	6559	93	42%	15	73				
Fermentor Agitator Shaft	21-Nov	6564	94	39%	15	134	213	37%	501.8	
Fermentor Agitator Shaft	21-Nov	6565	94	39%	15	79				
Fermentor Agitator Shaft	21-Nov	6566	94	39%	15	143	212	33%	499.4	
Fermentor Agitator Shaft	21-Nov	6567	94	39%	15	69				

Appendix C. Plant 3 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Fermentor Agitator Shaft	21-Nov	6568	94	39%	15	50	100	50%	235.6	
Fermentor Agitator Shaft	21-Nov	6569	94	39%	15	50				
Fermentor Agitator Shaft	21-Nov	6570	94	39%	15	58	112	48%	263.8	
Fermentor Agitator Shaft	21-Nov	6571	94	39%	15	54				
Rotary Vacuum Belt Filter	21-Nov	6572	75	27%	15	623	718	13%	1691.4	
Rotary Vacuum Belt Filter	21-Nov	6573	75	27%	15	95				
Rotary Vacuum Belt Filter	21-Nov	6574	75	27%	15	118	165	28%	388.7	
Rotary Vacuum Belt Filter	21-Nov	6575	75	27%	15	47				
Rotary Vacuum Belt Filter	21-Nov	6576	75	27%	15	703	815	14%	1919.9	
Rotary Vacuum Belt Filter	21-Nov	6577	75	27%	15	112				
Rotary Vacuum Belt Filter	21-Nov	6578	75	27%	15	113	162	30%	381.6	
Rotary Vacuum Belt Filter	21-Nov	6579	75	27%	15	49				
Rotary Vacuum Belt Filter	21-Nov	6580	75	27%	10	687	769	11%	2717.3	
Rotary Vacuum Belt Filter	21-Nov	6581	75	27%	10	82				
Rotary Vacuum Belt Filter	21-Nov	6582	75	27%	10	64	102	37%	360.4	
Rotary Vacuum Belt Filter	21-Nov	6583	75	27%	10	38				
Rotary Vacuum Belt Filter	21-Nov	6584	74	26%	10	607	722	16%	2551.2	
Rotary Vacuum Belt Filter	21-Nov	6585	74	26%	10	115				
Rotary Vacuum Belt Filter	21-Nov	6586	74	26%	10	80	135	41%	477.0	
Rotary Vacuum Belt Filter	21-Nov	6587	74	26%	10	55				
Rotary Vacuum Belt Filter	21-Nov	6588	75	27%	10	447	542	18%	1915.2	
Rotary Vacuum Belt Filter	21-Nov	6589	75	27%	10	95				
Rotary Vacuum Belt Filter	21-Nov	6590	75	27%	10	61	90	32%	318.0	
Rotary Vacuum Belt Filter	21-Nov	6591	75	27%	10	29				
Rotary Vacuum Belt Filter	21-Nov	6592	74	28%	10	639	758	16%	2678.4	
Rotary Vacuum Belt Filter	21-Nov	6593	74	28%	10	119				
Rotary Vacuum Belt Filter	21-Nov	6594	74	28%	10	74	114	35%	402.8	
Rotary Vacuum Belt Filter	21-Nov	6595	74	28%	10	40				
Rotary Vacuum Belt Filter	21-Nov	6596	75	24%	10	607	725	16%	2561.8	
Rotary Vacuum Belt Filter	21-Nov	6597	75	24%	10	118				
Rotary Vacuum Belt Filter	21-Nov	6598	75	24%	10	58	85	32%	300.4	
Rotary Vacuum Belt Filter	21-Nov	6599	75	24%	10	27				
Rotary Vacuum Belt Filter	21-Nov	6600	74	28%	10	559	648	14%	2289.8	
Rotary Vacuum Belt Filter	21-Nov	6601	74	28%	10	89				
Rotary Vacuum Belt Filter	21-Nov	6602	74	28%	10	66	89	26%	314.5	
Rotary Vacuum Belt Filter	21-Nov	6603	74	28%	10	23				
Rotary Vacuum Belt Filter	21-Nov	6604	75	24%	10	431	544	21%	1922.3	
Rotary Vacuum Belt Filter	21-Nov	6605	75	24%	10	113				
Rotary Vacuum Belt Filter	21-Nov	6606	75	24%	10	42	65	35%	229.7	
Rotary Vacuum Belt Filter	21-Nov	6607	75	24%	10	23				
Rotary Vacuum Belt Filter	21-Nov	6608	75	27%	10	415	492	16%	1738.5	
Rotary Vacuum Belt Filter	21-Nov	6609	75	27%	10	77				
Rotary Vacuum Belt Filter	21-Nov	6610	75	27%	10	45	59	24%	208.5	
Rotary Vacuum Belt Filter	21-Nov	6611	75	27%	10	14				
Rotary Vacuum Belt Filter	21-Nov	6612	75	24%	10	511	562	9%	1985.9	
Rotary Vacuum Belt Filter	21-Nov	6613	75	24%	10	51				

Appendix C. Plant 3 Bioaerosol Sampling Results (continued)

SAMPLE LOCATION	DATE	PLATE NUMBER	TEMPERATURE	HUMIDITY	SAMPLE TIME (min)	CORRECTED COUNT (CFU)	TOTAL COUNT (CFU)	PERCENT RESPIRABLE	CONCENTRATION (CFU/m ³)	PROCESS STRAIN
Rotary Vacuum Belt Filter	21-Nov	6614	75	24%	10	55	67	18%	236.7	
Rotary Vacuum Belt Filter	21-Nov	6615	75	24%	10	12				
Rotary Vacuum Belt Filter	21-Nov	6616	75	24%	10	463	532	13%	1879.9	
Rotary Vacuum Belt Filter	21-Nov	6617	75	24%	10	69				
Rotary Vacuum Belt Filter	21-Nov	6618	75	24%	10	35	59	41%	208.5	
Rotary Vacuum Belt Filter	21-Nov	6619	75	24%	10	24				

Appendix D. High-Volume Total Dust and Enzyme Sampling Results

SAMPLE LOCATION	PLANT	DATE	FILTER NUMBER	FLOW RATE (m3/min)	SAMPLE TIME (hr)	TOTAL DUST (ug)	TOTAL DUST (mg/m3)	ENZYME (DU/m3)
Ultrafilter	1	25-Jun	25-6	1.27	5.42	70.68	0.17	0.66
Ultrafilter	1	26-Jun	25-3	1.27	6.79	66.99	0.13	0.28
Ultrafilter	1	27-Jun	27-3	1.27	7.57	53.52	0.09	0.23
Ultrafilter	1	28-Jun	28-6	1.27	8.72	136.67	0.21	0.64
Candle Filter	1	25-Jun	25-5	1.30	5.05	144.44	0.37	0.32
Candle Filter	1	26-Jun	26-6	1.30	6.68	45.82	0.09	0.26
Candle Filter	1	27-Jun	27-2	1.30	7.57	35.09	0.06	0.21
Candle Filter	1	28-Jun	28-2	1.30	8.65	92.11	0.14	0.49
Blender Tank	1	25-Jun	25-7	1.19	5.07	49.57	0.14	0.34
Blender Tank	1	26-Jun	26-5	1.19	6.60	45.71	0.10	0.52
Blender Tank	1	27-Jun	26-2	1.19	7.50	35.21	0.07	0.20
Blender Tank	1	28-Jun	28-4	1.19	8.65	79.82	0.13	0.74
Fermentor	1	26-Jun	25-4	1.19	7.44	33.02	0.06	0.21
Fermentor	1	27-Jun	27-4	1.19	7.81	27.48	0.05	0.16
Fermentor	1	28-Jun	27-5	1.19	8.30	39.58	0.07	0.61
Outside-Background	1	28-Jun	28-1	1.25	7.68	99.12	0.17	0.27
Blank	1		25-1			-0.34		
Blank	1		25-2			-0.30		
Blank	1		25-8			-0.01		
Blank	1		26-1			0.50		
Blank	1		26-3			0.06		
Blank	1		26-4			-1.63		
Blank	1		26-7			-0.58		
Blank	1		27-1			-0.42		
Blank	1		27-6			0.23		
Blank	1		28-3			0.23		
Blank	1		28-5			0.95		
Weigh Station	2	10-Sep	1	1.47	7.43	113.58	0.17	
Weigh Station	2	10-Sep	7			-0.40		
Weigh Station	2	11-Sep	8	1.47	8.29	87.05	0.12	
Weigh Station	2	11-Sep	9			-0.12		
Weigh Station	2	12-Sep	15	1.47		6.88		
Weigh Station	2	12-Sep	16			0.12		
Weigh Station	2	13-Sep	22	1.47	4.19	135.13	0.37	
Dump Station	2	10-Sep	5	1.42	4.44	41.41	0.11	
Dump Station	2	11-Sep	11	1.42	7.70	75.14	0.11	
Dump Station	2	12-Sep	17	1.42		9.93		
Filter Press	2	10-Sep	2	1.30	7.10	56.35	0.10	
Filter Press	2	11-Sep	10	1.30	7.77	73.04	0.12	
Filter Press	2	12-Sep	20	1.30	5.80	66.13	0.15	
Filter Press	2	13-Sep	23	1.30	4.31	39.72	0.12	
Aging Tanks	2	10-Sep	3	1.36	6.93	55.65	0.10	
Aging Tanks	2	11-Sep	14	1.19	6.67	63.44	0.13	
Aging Tanks	2	12-Sep	21	1.19	5.69	20.75	0.05	
Fermentor Tank - agitator shaft	2	10-Sep	4	1.19	6.19	37.40	0.08	
Fermentor Tank - agitator shaft	2	10-Sep	6			0.01		

Appendix D. High-Volume Total Dust and Enzyme Sampling Results (continued)

SAMPLE LOCATION	PLANT	DATE	FILTER NUMBER	FLOW RATE (m3/min)	SAMPLE TIME (hr)	TOTAL DUST (ug)	TOTAL DUST (mg/m3)	ENZYME (DU/m3)
Fermentor Tank - agitator shaft	2	11-Sep	12	1.19	6.90	41.72	0.08	
Fermentor Tank - agitator shaft	2	11-Sep	13			-0.25		
Fermentor Tank - agitator shaft	2	12-Sep	18	1.19	5.76	16.70	0.04	
Fermentor Tank - agitator shaft	2	12-Sep	19			0.16		
Drop Tank Room	3	18-Nov	MF-6	1.56	0.09	8.20	0.04	
Drop Tank Room	3	19-Nov	MF-10	1.56	0.37	35.00	0.05	
Drop Tank Room	3	20-Nov	MF-25	1.56	1.21	113.00	0.15	
Drop Tank Room	3	21-Nov	MF-27	1.56	8.73	815.10	1.11	
Outside Dump Station Room	3	18-Nov	MF-7	1.47	0.59	51.90	0.24	
Outside Dump Station Room	3	19-Nov	MF-9	1.47	2.88	254.00	0.35	
Outside Dump Station Room	3	20-Nov	MF-26	1.47	5.99	529.00	0.75	
Outside Dump Station Room	3	21-Nov	MF-28	1.47	6.00	530.00	0.76	
Rotary Filter	3	18-Nov	MF-2	1.42	0.06	5.30	0.04	
Rotary Filter	3	19-Nov	MF-14	1.42	0.50	42.20	0.06	
Rotary Filter	3	21-Nov	MF-30	1.42	2.02	172.00	0.25	
Centrifuge Room	3	18-Nov	MF-4	1.42	0.15	12.60	0.09	
Centrifuge Room	3	19-Nov	MF-12	1.42	0.35	29.90	0.04	
Centrifuge Room	3	20-Nov	MF-24	1.42	1.33	113.00	0.17	
Centrifuge Room	3	21-Nov	MF-29	1.42	0.77	65.60	0.10	
Agitator Fermentor #3	3	18-Nov	MF-5	1.47	0.12	10.40	0.05	
Agitator Fermentor #3	3	19-Nov	MF-15	1.47	0.27	23.50	0.05	
Agitator Fermentor #3	3	20-Nov	MF-22	1.47	1.53	135.00	0.22	
Agitator Fermentor #3 Near Wall	3	21-Nov	MF-31	1.47	1.27	112.00	0.16	
Blank	3	21-Nov	MF-18			-2.10		
Blank	3	19-Nov	MF-11			-1.60		
Blank	3	20-Nov	MF-20			-1.80		
Blank	3	21-Nov	MF-19			-2.40		
Blank	3	18-Nov	MF-1			-0.40		
Blank	3	18-Nov	MF-3			-0.40		
Blank	3	19-Nov	MF-13			-1.50		
Blank	3	20-Nov	MF-21			-1.60		

Appendix E. Cassette Total Dust Sampling Results

SAMPLE LOCATION	PLANT	DATE	FILTER NUMBER	FLOW RATE (l/min)	SAMPLE TIME (hr)	TOTAL DUST (mg)	TOTAL DUST (mg/m3)
Blending Tank 1	1	25-Jun	102	2.21	6.36	-0.03	0.02
Blending Tank 1	1	26-Jun	112	2.20			
Blending Tank 1	1	27-Jun	178	2.21	8.27	0.02	0.02
Blending Tank 2	1	25-Jun	145	2.20	6.35	0.04	0.05
Blending Tank 2	1	26-Jun	109	2.20	8.30	0.02	0.02
Blending Tank 2	1	27-Jun	184	2.22	8.22	0.1	0.09
Blending Tank 2	1	28-Jun	189	2.21	8.80	0.14	0.12
Candlefilter	1	25-Jun	111	2.21	6.38	-0.01	0.02
Candlefilter	1	26-Jun	101	2.20	8.28	0.05	0.05
Candlefilter	1	27-Jun	154	2.21	8.26	0.05	0.05
Candlefilter	1	28-Jun	160	2.20	8.80	0.19	0.17
Dumpster	1	25-Jun	123	2.21	6.54	0.05	0.06
Dumpster	1	26-Jun	116	2.20	8.43	0.03	0.02
Dumpster	1	27-Jun	192	2.20	8.37	0.21	0.19
Dumpster	1	28-Jun	157	2.20	9.00	0.06	0.05
Dumpster	1	25-Jun	122	2.21	6.50	-0.01	0.02
Dumpster	1	26-Jun	114	2.20	8.39	-0.01	0.02
Dumpster	1	27-Jun	162	2.20	8.35	0.24	0.22
Dumpster	1	28-Jun	153	2.22	9.00	0.31	0.26
Sampling Port	1	25-Jun	135	2.21	6.50	0.06	0.07
Sampling Port	1	26-Jun	104	2.20	8.44	-0.07	0.02
Sampling Port	1	27-Jun	174	2.21	8.35	0.05	0.05
Fermentor Tank	1	25-Jun	103	2.20	6.43	-0.05	0.02
Fermentor Tank	1	26-Jun	146	2.22			
Fermentor Tank	1	27-Jun	148	2.20	8.35	0.07	0.07
Fermentor Tank	1	25-Jun	139	2.20	6.42	0	0.02
Fermentor Tank	1	26-Jun	115	2.20			
Fermentor Tank	1	27-Jun	191	2.20	8.37	0.05	0.05
Filter Press - belt conveyor	1	25-Jun	128	2.21	6.80	0.07	0.08
Filter Press - belt conveyor	1	26-Jun	126	2.20	8.39	0	0.02
Filter Press - belt conveyor	1	27-Jun	156	2.21	8.29	0.3	0.28
Filter Press - belt conveyor	1	28-Jun	176	2.20	8.96	0.11	0.1
Filter Press - left	1	25-Jun	131	2.20	6.88	-0.01	0.02
Filter Press - left	1	26-Jun	106	2.21	8.38	-0.03	0.02
Filter Press - left	1	27-Jun	179	2.20	8.30	0.21	0.2
Filter Press - left	1	28-Jun	170	2.21	8.99	0.04	0.04
Filter Press - right	1	25-Jun	138	2.20	6.89	0.01	0.02
Filter Press - right	1	26-Jun	127	2.22	8.38	0.01	0.02
Filter Press - right	1	27-Jun	193	2.21	8.28	0.43	0.4
Filter Press - right	1	28-Jun	168	2.21	8.93	0.14	0.12
Incubation Room	1	25-Jun	130	2.21	7.03	0.01	0.02
Incubation Room	1	26-Jun	117	2.21	8.38	-0.02	0.02
Mash Treatment Tank	1	26-Jun	105	2.21	8.16	-0.02	0.02
Mash Treatment Tank	1	27-Jun	173	2.20	8.37	0.05	0.05
QC Laboratory	1	26-Jun	110	2.21	8.31	0.06	0.06
QC Laboratory	1	27-Jun	180	2.20			

Appendix E. Cassette Total Dust Sampling Results (continued)

SAMPLE LOCATION	PLANT	DATE	FILTER NUMBER	FLOW RATE (l/min)	SAMPLE TIME (hr)	TOTAL DUST (mg)	TOTAL DUST (mg/m ³)
Recovery - dump station	1	25-Jun	142	2.20	6.74	0	0.02
Recovery - dump station	1	26-Jun	107	2.20	8.40	-0.02	0.02
Recovery - dump station	1	27-Jun	161	2.21	9.02	4.29	3.59
Recovery - work table	1	25-Jun	129	2.20	6.76	0.05	0.06
Recovery - work table	1	26-Jun	125	2.21	8.40	0.06	0.06
Recovery - work table	1	27-Jun	151	2.21	8.32	0.15	0.14
Scrubber	1	25-Jun	121	2.20	6.45	0.01	0.02
Scrubber	1	26-Jun	144	2.21			
Scrubber	1	27-Jun	175	2.20	8.29	0.04	0.04
Seed Tank	1	26-Jun	136	2.20	8.26	0.09	0.09
Seed Tank	1	27-Jun	183	2.21	8.18	0.06	0.06
Ultrafilter	1	25-Jun	141	2.22	6.30	0.1	0.12
Ultrafilter	1	26-Jun	140	2.21	8.27	-0.01	0.02
Ultrafilter	1	27-Jun	147	2.20	8.28	0.05	0.05
Blank	1	28-Jun	150			0.1	
Blank	1	28-Jun	166			-0.2	
Blank	1	28-Jun	164			0.2	
Blank	1	26-Jun	119			-1	
Blank	1	26-Jun	120			-0.3	
Blank	1	26-Jun	132			-0.6	
Blank	1	26-Jun	124			-0.8	
Blank	1	26-Jun	108			-0.4	
Blank	1	25-Jun	143			-3.2	
Blank	1	25-Jun	134			-0.5	
Blank	1	25-Jun	137			-0.6	
Blank	1	25-Jun	113			-0.6	
Blank	1	25-Jun	118			-0.7	
Blank	1	25-Jun	133			-0.7	
Blank	1	27-Jun	152			-0.4	
Blank	1	27-Jun	181			0.2	
Blank	1	27-Jun	177			0.2	
Blank	1	27-Jun	182			0.9	
Blank	1	27-Jun	172			0.1	
Right of baler	3	20-Nov	MTF-5	2.5	7.45	0	0
Dump station near baler	3	19-Nov	MTF-1	2.5	6.93	0.3	0.29
Near hopper	3	19-Nov	MTF-2	2.5	6.82	0.3	0.29
Dump station	3	20-Nov	MTF-7	2.5	7.6	0.4	0.36
Blank	3	20-Nov				-0.2	
Blank	3	20-Nov				-0.1	
Blank	3	19-Nov				0.1	
Blank	3	19-Nov				-0.1	

Appendix F. Plant 1 Acetone Results

SAMPLE LOCATION	DATE	CHARCOAL TUBE NO.	FLOW RATE (cc/min)	SAMPLE TIME (hr)	ACETONE (ng)	ACETONE (ng/m3)
Filter press	25-Jun	165	49.6	0.94	<0.01	
Filter Press - rail	25-Jun	162	51.9	0.95	<0.01	
Filter Press - rail	28-Jun	173	49.2	0.93	0.01	3.64
Filter Press - rail	28-Jun	176	49.2	0.95	<0.01	
Conveyor	25-Jun	163	52.2	0.93	<0.01	
Conveyor	28-Jun	179	51.2	0.95	<0.01	
Conveyor	28-Jun	174	51.2	0.85	<0.01	
Mash Tank	28-Jun	181	51.9	0.95	<0.01	
Mash Tank	28-Jun	177	51.9	0.82	<0.01	
Mash Tank	28-Jun	184	51.9	0.99	<0.01	
Blank	28-Jun	164			<0.01	
Blank	28-Jun	172			<0.01	
Blank	28-Jun	178			<0.01	
Blank	28-Jun	180			<0.01	
Blank	28-Jun	167			<0.01	
Blank	25-Jun	171			<0.01	
Blank	25-Jun	166			<0.01	
Blank	27-Jun	172			<0.01	

