WORK PRACTICES *for*

Handling Enzymes *in the* Detergent Industry

Handling Enzymes *in the* Detergent Industry

The Soap and Detergent Association
New York, NY

http://www.sdahq.org

NOTICE

This document is written for use by the cleaning products industry. It may also be used as a reference by other industries employing enzyme technology. However, the practices set forth in this document are offered solely as references for companies involved in handling enzymes within the soap and detergent industry. The information presented here may not be entirely applicable to all enzyme handling situations; that will depend on the nature of the operations and the extent of exposure.

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None of the enzyme handling practices presented should be construed as binding or generally accepted standards or practices within the soap and detergent or any other industry. Following these practices is not a substitute for the independent discretion and expert judgment that are necessary to the handling of enzymes. Accordingly, neither The Soap and Detergent Association nor its member companies assume any responsibility or liability whether based on warranty, contract, negligence, strict liability, product liability or otherwise with respect to the information and practices contained herein.

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I. INTRODUCTION

This document provides information on safe enzyme handling practices for plant managers, industrial hygienists, occupational and safety professionals, medical personnel and employees in the detergent industry. It includes a medical surveillance program describing measures the employer can use to help ensure employee health and safety in the workplace.

This document is written for use by the cleaning products industry. It may also be used as a reference by other industries employing enzyme technology. The information presented here may not be entirely applicable to all enzyme handling situations. Its applicability will depend on the nature of the operations, the materials being utilized and the extent of exposure. In all cases, the user of this document must recognize that this publication is not a substitute for independent evaluations utilizing the opinions of professionals in the areas of safety and health, law, medicine, industrial hygiene and industrial engineering.

For additional information on the safe use of enzymes in the workplace and proper enzyme handling, contact your supplier; The Soap and Detergent Association, 475 Park Avenue South, New York, NY 10016, Telephone: 212-725-1262; or the Enzyme Technical Association, 1575 I Street, N.W., Washington, DC 20005, Telephone: 202-789-7380.

II. BACKGROUND

What Are Enzymes?

As components of living organisms, enzymes are complex proteins produced by virtually all living organisms to speed up chemical reactions necessary to maintain life. However, enzymes themselves are not living organisms.

The principal reason for including these complex proteins in detergents is their ability to catalyze (speed up) specific reactions. The reactions catalyzed by enzymes involve the "breaking down" of certain stains into their basic components. As an example, protease breaks peptide bonds in proteins. The break-down products formed from the reactions of enzymes can then be removed more easily by other ingredients of the detergent product.

Enzymes are generally named after the reactions they catalyze. Amylases catalyze reactions with carbohydrates (amyl is Greek for starch); cellulases react with cellulose; lipases react with lipids (e.g., fats and oils); proteases react with proteins. The catalytic action of an enzyme is due to the existence of active sites on the enzyme surface which allow the formation of an enzyme-soil complex. Each enzyme has a specifically shaped active site which fits together with a specific soil type, similar to a lock and key. If the soil does not fit the shape of the active site, no reaction occurs and the soil is not broken down.

In terms of classical safety testing, enzymes have a low order of toxicity. Some types of enzymes (e.g., proteases) are mildly irritating to skin and eyes. They are not skin sensitizers (Griffith et al., 1969). The main safety concern associated with enzymes is the induction of respiratory allergies. As described below, when enzymes were first used in detergent formulations, some employees in detergent manufacturing facilities developed relatively severe allergy symptoms. Today, with appropriate control of airborne enzyme protein, enzyme-containing detergents can be produced with little or no risk to employees.

Historical Perspective of Enzyme Use in Laundry Products

Enzymes have been used in cleaning applications to remove stains since the early 1900s. However, large-scale incorporation of enzymes into detergent formulations did not begin until the late 1960s. One of the primary reasons that prevented enzyme use in detergents was the alkalinity of these formulations, which inactivated the enzymes. However, in the late 1950s and early 1960s, a serine protease was developed that was stable under alkaline conditions. Additionally, new techniques for producing enzymes in the large quantities needed by the detergent industry were developed. The performance advantage of enzymes in laundry detergents was quickly recognized. Enzymes were introduced into formulations by 1963. By 1969, 80% of all laundry detergent products contained enzymes.

Manufacturing Safety Issues

Companies formulating with enzymes initially underestimated the potency of enzymes. Inadequate understanding of the control measures needed during the handling of protease preparations and finished product resulted in frequent cases of skin irritation at detergent manufacturing facilities.

Publications then appeared which indicated that employee exposure to enzymes could lead to allergic respiratory responses (Flindt, 1969 and Pepys et al., 1969). The reported symptoms varied from light hay fever symptoms to more severe asthma-like attacks. Some investigators suggested enzymes could lead to severe and permanent lung damage. This suggestion was later disproved.

Resolution of Issues

The U.K. Soap and Detergent Industry Association (SDIA) formed The Committee on Enzyme Washing Products in September, 1969. This committee investigated ways to reduce potential occupational exposures. That research led to the development of industrial hygiene and employee health monitoring recommendations.

Extensive and successful efforts were made by the soap and detergent industry and enzyme manufacturers to reduce the exposure of factory employees to enzyme and detergent aerosols (i.e., dusts and mists). Significant reductions in exposure resulted from:

1) the development of low-dust encapsulated enzymes;
2) capital-intensive manufacturing site improvements; and
3) improved industrial hygiene practices and procedures.

The situation that had developed at the manufacturing sites led to concerns for consumers. In 1969, the New York Academy of Sciences initiated a discussion of enzyme safety. As a result, the Food and Drug Administration (FDA) began an investigation in early 1970. By November 1970, The National Academy of Sciences and The National Research Council (NRC) were commissioned by the FDA to study the risks of enzymes in consumer products. It was concluded that consumers using detergents containing enzymes did not develop respiratory allergies to enzymes through product use (NRC, 1971).

This conclusion was confirmed by Pepys et al. (1973) in which thousands of allergic patients were skin prick tested. Eighty percent of those patients used enzyme-containing detergents. Of the population studied, 40% were highly atopic, meaning 40% had a high tendency to be sensitized, 40% were moderately atopic and 20% were non-atopic (see section IX for discussion of medical terminology). There were no relevant skin prick test reactions to enzyme preparations in this study. This study provided strong evidence that consumers of enzyme-containing products did not develop a specific form of allergy to enzymes through product use. The enzyme specific allergy is known as an immediate hypersensitivity (Type I hypersensitivity). It involves IgE antibodies and is mediated by the release of histamine.

Because of issues raised at manufacturing sites, additional studies were undertaken to build the safety data base (Griffith et al., 1969). These additional studies included skin irritation studies, mildness tests on almost 6,000 housewives, diaper rash studies on 360 infants, and repeated insult patch tests of almost 1,500 people. It was demonstrated that adding

enzymes to detergents does not alter the detergent safety profile. The overall conclusion was that studies of "enzyme-containing synthetic detergent and presoak formulations have shown them to be equivalent to comparable non-enzyme formulations ...".

Another report assessed in-home use by over 4,000 consumers of detergents that contained a protease enzyme (Bolam et al., 1971). The researchers concluded that:

> "... detergents containing proteolytic enzymes had no greater effect on the skin than conventional detergents, even when the hand skin condition was initially poor. The same was true in a further test on 130 housewives with 'dishpan' hands. No adverse reactions attributable specifically to the enzyme products were seen. No eruptions from contact with clothes washed in enzyme products were reported from any of the families involved in these tests."

A major symposium regarding the biological effects of proteolytic enzyme detergents took place in Cardiff, Wales (1976). This conference was attended by engineers, epidemiologists, immunologists, occupational physicians, respiratory physiologists and statisticians. One conclusion from this 1976 meeting was that "Exposure levels during the manufacture of the enzyme and enzyme containing detergents can now be kept so low that very few people will become sensitized."

Many Years of Safe Use

Liquid and granule detergents containing enzymes have been produced safely for over 20 years. The development of non-dusty encapsulated enzyme preparations, improved dust-control equipment, plant design improvements and strict industrial hygiene practices have minimized new cases of sensitizations among detergent industry employees (see sections VI and VII for details). The overall conclusion is that enzyme-containing detergents can be manufactured safely, assuming care is taken to minimize employee exposure to enzyme protein.

References

Bolam, R.M., Hepworth, R. and Bowerman, L.T. In-use Evaluation of Safety to Skin of Enzyme Containing Washing Products. British Medical Journal. 1971, Vol.2, 499-501.

Griffith, J.E., Whitehouse, H.S., Pool, R.L., Newmann, E.A. and Nixon, G.A. Safety Evaluation of Enzyme Detergents. Oral and Cutaneous Toxicity, Irritancy and Skin Sensitization Studies. Fd. Cosmet. Toxicol. 1969, Vol. 7 (6), 581-593.

Flindt, M.L.H. Pulmonary Disease Due to Inhalation of Derivatives of *Bacillus subtilis* Containing Proteolytic Enzymes. Lancet. 1969, Vol. 1 (607), 1177-1181.

National Research Council (NRC). Enzyme-containing Laundering Compounds and Consumer Health. 1971.

Pepys, J., Longbottom, J.L., Hargreane, F. E. and Faux, J. Allergic Reactions of the Lungs to Enzymes of *Bacillus subtilis*. Lancet. 1969, Vol. 1 (607), 1181-1184.

Pepys, J., Wells, I.D., D'Souza, M.F. and Greenberg, M. Clinical and Immunological Responses to Enzymes of *Bacillus subtilis* in Factory Workers and Consumers. Clinical Allergy. 1973, Vol. 3 (2), 143-160.

The Soap and Detergent Industry Association (SDIA). The Standing Committee on Enzymatic Washing Products. Fifth Report, June 1991. Hayes, Middlessex, UB4 0JD, England.

Symposium in Cardiff, Wales. Biological Effects of Proteolytic Enzyme Detergents. Thorax. 1976, Vol. 31 (6), 621-634.

III. ROUTES OF EXPOSURE AND POSSIBLE HEALTH EFFECTS

Introduction

Exposure to enzymes may cause irritation and/or allergies. As explained below, exposure can occur via inhalation or through skin or eye contact.

Inhalation

Allergies to enzymes are no different than allergies to other materials such as house dust, animal dander or pollen. If enough enzyme is inhaled, the body will begin to recognize the enzyme as a foreign material and produce allergic antibodies. Once allergic antibodies are produced, the individual is said to be sensitized. Sensitization by itself is not a disease, but rather an indication of exposure. In individuals who have become sensitized, further breathing of high levels of enzyme aerosol can trigger allergy symptoms ranging from watery eyes, a runny nose and scratchy throat to occupational asthma. When exposure to enzymes is discontinued, allergy symptoms should disappear.

Depending on the type and amount of enzyme, inhalation of extremely high levels of protease aerosols may also cause direct irritation of the respiratory tract, resulting in symptoms like those seen in people with allergies. These symptoms include congestion, difficult breathing, sore throat or a runny nose. These symptoms are due to irritation of the respiratory or mucous tissues and can develop in both sensitized and non-sensitized persons if the exposure level is sufficient. Irritation is very rare since it requires very high levels of exposure. It should not occur when adequate controls are in place. When exposure to enzymes is discontinued, symptoms disappear and pulmonary function should return to normal.

Skin

Enzymes are not skin sensitizers (Griffith et al., 1969). However, skin surfaces in prolonged contact with high concentrations of proteases may become irritated. When skin contact with small quantities of enzymes is anticipated, irritation can be avoided by frequently washing exposed skin surfaces. Exposed areas should be protected by the use of gloves and other protective clothing whenever the potential for gross skin contact exists. The irritant response is characterized by a weeping, red glistening appearance of the skin surfaces, usually involving hands and fingertips, which can be painful. This reaction is due to the primary irritant characteristic of proteases and is not an allergic response. When exposure is discontinued, irritation should disappear.

Eye

Detergents or enzymes in contact with the eye may cause irritation unless thoroughly rinsed with water. The presence of enzymes in detergents does not necessarily increase the severity of the irritation. Again, removing the source of irritation should result in disappearance of symptoms. Appropriate eye protection should be used where there is significant potential for eye contact.

References

Griffith, J.E., Whitehouse, H.S., Pool, R.L., Newmann, E.A. and Nixon, G.A. Safety Evaluation of Enzyme Detergents. Oral and Cutaneous Toxicity, Irritancy and Skin Sensitization Studies. Fd. Cosmet. Toxicol. 1969, Vol. 7 (6), 581-593.

IV. EDUCATION

The following are suggestions for educating employees and contractors about the importance of safe enzyme handling practices. Proper training is essential for the safe use of materials in an industrial setting. It is important that people understand not only what is required of them but also why. It is the responsibility of every company to ensure that employees and contractors handling enzymes and enzyme products are adequately trained. They must have adequate knowledge of the potential health effects of enzymes and safe work practices associated with their use. Information provided on enzymes should include the nature of the effect, risks to health arising from exposure, routes of entry into the body, the anticipated degree of exposure, and any factors that may increase risk. Employees should know proper practices and procedures for working with enzymes and enzyme-containing products.

Employees and contractors should understand:

— Reasons for an education program
— Reasons for medical surveillance
— Health effects of enzymes
— Proper use of control measures:
  - engineering
  - administrative
  - personal protection
— Emergency procedures

Instruction manuals, safe practices, and/or standard operating procedures for the handling of enzyme preparations and enzyme products should be written for the individual workplace at a level suitable for the work force. These should take into account the types of enzymes and equipment used and the types of products that are manufactured.

All employees and contractors involved in the use of enzyme materials must be briefed on their potential effects and adequately trained in the relevant operations specified in the standard operating procedures before working with these materials. These operations should include all checks on the environmental control systems (e.g., ventilation, static pressure, etc.) to ensure their correct and safe operation. Only responsible, trained personnel should handle enzyme preparations, as mistakes, spills or plant malfunctions could potentially result in the release of enzyme aerosol. All such employees should be trained in cleaning and spill recovery procedures. In addition, all emergency response personnel should be informed of the potential health effects of enzyme preparations.

Education and training are also required by the Occupational Safety and Health Administration (OSHA) under its Hazard Communication (HAZCOM) Standard (OSHA 29 CFR 1910.1200). This regulation requires that the employer prepare a written hazard communication program and provide employees with information and training on hazardous chemicals. To satisfy these OSHA requirements, employers may wish to document

and retain training program records, including employee attendance records, program contents and instructor qualifications.

Where personnel are required to use personal protective equipment, education and training are also required. This training includes the proper equipment selection, as well as training in its use and maintenance. OSHA regulations on personal protective equipment are found at 29 CFR 1910.132-138.

References

Occupational Safety and Health Administration (OSHA), 29 CFR 1910.1200 (Hazard Communication).

Hazard Communication; 29 CFR 1910.132.

Personal Protective Equipment; General requirements 29 CFR 1910.133.

Eye and Face Protection; 29 CFR 1910.134.

Respiratory Protection; 29 CFR 1910.120.

Hazardous Waste Operations and Emergency Response.

V. ENZYME PREPARATIONS: COMMUNICATION OF SAFETY INFORMATION

Safety Information

Material Safety Data Sheets (MSDS) and labels provided by the supplier are important sources of information on the handling of enzyme preparations and are required by OSHA. Information found on MSDSs and labels helps the user identify safety precautions necessary to maintain effective employee health protection measures. OSHA HAZCOM regulations require that MSDS labels be provided by the supplier and require that employees be trained in the hazards for all chemicals to which they are exposed. MSDSs must be readily available in the workplace. The HAZCOM standard also has a labeling requirement.

Material Safety Data Sheets

A current MSDS must be provided by the enzyme supplier. Employees and their supervisors must have ready access to the MSDS before the first supply of a new enzyme is permitted in the workplace. MSDSs must be readily available to employees at all times.

Labels

Labels on the enzyme container should include a standard identification label and a hazard warning label providing sufficient information to permit safe use of the enzyme. It is the responsibility of the enzyme manufacturer to ensure that enzyme containers are clearly and appropriately labeled.

Description and Composition of Enzyme Preparations

Enzyme preparations are supplied in the form of powders, granules, liquids or slurries. They contain enzymes and various inert ingredients compatible with other substances used in the end products. One or more enzyme proteins can represent a small percentage of the total enzyme preparation.

In general, the objective should be to use the product in a physical form that will minimize the potential for generating respirable aerosols containing enzymes. Powder preparations generally have the greatest potential for generating respirable aerosols. Commercially available granulated products have excellent low-dust and abrasion resistance characteristics. Slurries are more viscous than liquids. Both slurries and liquids are designed for incorporation into liquid detergent products with a minimum potential for aerosol formation.

The product manufacturer must ensure that enzyme preparations are supplied according to specification. For example, the quality of the granule can be verified by conducting periodic tests, for example, by elutriation (SDIA, 1991) or the Heubach procedure (Plinke et al., 1992).

References

Plinke, A.E., Maus, R. and Leith, D. Experimental Examination of Factors That Affect Dust Generation by Using Heubach and MRI Testers. American Industrial Hygiene Association Journal. May 1992, Vol. 53.

The Soap and Detergent Industry Association (SDIA). The Standing Committee on Enzymatic Washing Products. Fifth Report, June 1991. Hayes, Middlessex, UB4 0JD, England.

Occupational Safety and Health Administration (OSHA), 29 CFR 1910.1200 (Hazard Communication).

VI. CONTROL TECHNOLOGY

Introduction

The goal of an enzyme safety program is to prevent employee exposure to enzymes that will adversely affect their health (SDIA, 1991). A primary route of enzyme exposure is inhalation. Therefore, a primary method of controlling exposures to enzymes is to prevent or contain enzyme aerosolization. Engineering controls are the preferred method of preventing enzyme aerosolization. Work-practice controls are used in combination with engineering controls to limit employee exposure. Finally, personal protective equipment is used to supplement engineering and work-practice controls, when both are not feasible, or in the event of emergencies, such as spills, or during high exposure tasks such as clean outs. Guidelines for airborne exposure are discussed in section VII. E.

Aerosolization Considerations

In this document, aerosols are defined as airborne solid or liquid substances. Aerosols are generally classified as dusts, mists, fumes, smokes and fogs. Of these classifications, enzyme preparations can be in the form of dusts and mists.

Both enzyme physical preparation form and handling procedures greatly influence the potential for aerosolization and the selection of appropriate control technology. Powdered enzyme preparations present the greatest potential for exposure because they are easily aerosolized. Granular enzyme preparations encapsulate the enzyme to prevent its release into the air. They have very low dusting capabilities but care must be taken not to crush them. Liquid or powdered detergent products containing enzymes also have a potential for aerosol formation. Aerosol generation is most likely to occur during process upsets, clean up or container filling.

Engineering Controls

Enzyme and detergent aerosols are best contained by engineering controls, in particular, enclosure supplemented with the use of local exhaust ventilation (LEV). The unique characteristics of each situation should be evaluated by a qualified ventilation expert. Control measures should be tailored to the specific situation.

Attachment 1 contains a more detailed synopsis of general ventilation principles. Key factors to take into account are overall plant design, location of the ventilation controls, design specification, performance verification, system maintenance, management of process changes and dilution ventilation.

1. Process Design

Strong consideration should be given to the following measures while designing or implementing enzyme addition operations:

- Add enzymes as late as possible in the process in order to minimize the need for engineering controls.

- Select processes and equipment that minimize aerosol generation.
- Maintain enzyme-containing equipment at a negative pressure in order to ensure inward air flow at all openings. Specific guidance should be given for each situation by qualified ventilation personnel.
- Enzyme addition operations should be contained/enclosed.
- Provision should be made for spill containment of both enzyme preparations and detergents containing enzymes.

2. Location of Enclosure and Local Exhaust Ventilation (LEV)

The following areas are normally serviced by enclosure and LEV controls:

- Areas where enzyme preparations are added into the plant dosing system.
- All conveyors and areas containing enzymes up to and including the area where the enzyme preparations enter the product stream.
- Conveyors carrying finished product prior to packing.
- Filling heads of packing machines.
- Areas where scrap product from the operation and/or returned product is reclaimed.

3. Design Specification

Specific advice should be given for each situation by qualified ventilation personnel. In general, face velocities of air are maintained at an inward flow (negative pressure) at openings where enzyme-containing product could escape. The inward airflow must be sufficient to prevent release of enzyme and detergent aerosol into the ambient environment. The effect of opening doors and windows on the ventilation system should be considered in the design.

4. Performance Verification

Prior to installation, a qualified ventilation person and system vendor should agree as to where pressure and flow velocity measurements should be taken and minimum acceptable values. After installation, the system needs to be balanced and the performance verified. Additionally, performance needs to be verified by air monitoring as discussed in section VII.

5. System Maintenance

Maintenance is an integral part of ensuring an adequate ventilation system. A qualified ventilation expert and the system vendor are best able to advise on a preventive maintenance program. Overall accountability for the

system should be specifically assigned and written records such as the following should be maintained and updated:

- Limitations of operation.
- Required maintenance tasks.
- Maintenance frequency.
- Designation of a responsible individual for each maintenance task.
- Records of maintenance checks, including air flow and pressure measurements.

6. Management of Process Changes

Ad hoc additions or changes to any part of the system can possibly have a profound effect on the overall performance. A procedure for managing changes should be in place to ensure that appropriate professional advice is obtained prior to changing the system in any way. Appropriate measures should be taken after the change to ensure that the system performs as desired.

7. Dilution Ventilation

Dilution ventilation is defined as the dilution of contaminated air with uncontaminated air in a general area, room or a building for the purpose of health hazard control (ACGIH, 1988). Dilution ventilation can be used to supplement LEV. However, the use of dilution ventilation as a substitute for LEV is not recommended. Obtaining the advice of a specialist to prevent costly over or under design is recommended before installing dilution ventilation.

Work-practice Controls

Work-practice controls include appropriate management systems and operational controls, education, safe work practices and good housekeeping practices.

1. Management Systems

Accountability for maintaining the necessary hygiene standards should be clearly defined and assigned to the appropriate level of management. Responsibilities for daily management of the program should be clearly delegated to operating personnel. Companies should ensure that personnel trained in medicine, industrial hygiene, and/or engineering verify that these company standards are being adhered to. Access to potentially high exposure areas such as enzyme addition areas should be restricted to qualified employees.

2. Operational Controls

Enzyme operations should seek to achieve:

- No visible dust.
- No recurring spills.
- No prolonged 'temporary' repairs.
- No gross skin contact.
- Prevention/containment of aerosol generation.

These goals are achieved through a combination of engineering and work-practice controls.

3. Education

The role of education is discussed in section IV. It is important to periodically educate employees and contractors and test their knowledge in areas such as:

Health effects of enzymes.
- Reasons for the program.
- Reasons for and use of control measures (engineering, administrative and personal protection). Use of control measures should be tailored to thesituation.
- Contingency measures, e.g., what to do in the event of a spill or a medical emergency.

Education should be repeated at a frequency dictated by worker recall or reassignment. This will help achieve better compliance with safe work procedures. Annual retraining and re-testing have proven effective in some companies.

4. Safe Work Practices

Safe work practices are most effective when workers participate in their development. Education and industrial hygiene support need to be provided as necessary. Operational management and health and safety professionals should review the final program of safe practices to ensure quality and completeness.

A review of the safe work practices should be conducted annually and updated as needed, particularly whenever operational changes require modification to those practices. Safe work practices include:

- Spills and equipment should be cleaned by vacuums equipped with high efficiency particulate air (HEPA) filters or dedicated central vacuum systems. Do not brush or sweep, as it generates aerosols. Liquid spills may be mopped or vacuumed. Wash downs should use cold low pressure water or water spray portable vacuum cleaners.
- Do not use high pressure water, steam or vacuums without HEPA filters.
- Washing facilities should be accessible, convenient and well maintained.
- Good personal hygiene should be encouraged and practiced.
- Enzymes should be stored in dedicated areas prior to use.

Operations where written safe work practices are implemented include:

- Receipt, movement and storage of enzyme preparations.
- Addition of enzyme to the plant dosing system from bulk raw materials.
- Disposal of empty raw material containers.
- Manipulation of bulk product containing enzymes during the manufacturing process.
- Maintenance work involving exposure to equipment containing (or previously containing) product or enzyme preparations.
- Scrap reclaim.
- Clean up of spills.
- Ventilation systems and maintenance.

Personal Protective Equipment

1. General Comments

The use of personal protective equipment (PPE) is appropriate when a combination of engineering and work-practice controls is not sufficient or practical to control enzyme exposures. There are some operations where PPE must be used as the primary control method, such as spill clean up. More often it is used to supplement other control methods. Types of PPE that are commonly used for protection against enzymes include respiratory, eye and skin protection equipment. PPE is covered by OSHA standards (OSHA, 29 CFR Subpart I 1910.132 - 138). General requirements of PPE are specified in 1910.132 and include application, design, hazard assessment, equipment selection and training. A qualified health and safety professional should be consulted for selection of personal protective equipment, especially respiratory protection.

2. Respiratory Protection

Respiratory protection is used in instances where engineering and work-practice controls are not able to sufficiently control airborne enzyme to a safe level (AIHA, 1992). A respiratory protection program must be established in accordance with OSHA standard (29 CFR Subpart I, 1910.132 -138) prior to instituting respirator use. This program includes respirator selection, training, fit testing, medical surveillance, respiratory hazard assessment, maintenance, cleaning, inspection and storage.

Respirator selection is a key element in the respiratory protection program. The type of respirator selected is based on the level of enzyme, time spent in the area and worker activity. Air monitoring programs provide information on the plant operations requiring the use of respirators and the level of protection required. The various classes of respirators are assigned protection values which are based on a respirator's ability to reduce the airborne contaminant level. For example, half-face respirators have a protection factor of 10. Therefore, this class of respirators can reduce worker exposure 10-fold when used properly. The respirator protection factor is used along with air monitoring results to select an appropriate respirator.

There are three main classes of respirators: air purifying, air supplied and self-contained breathing apparatus. The air purifying respirators are the most commonly used respirator in detergent facilities. The air purifying respirators use a cartridge to remove contaminants from the air. For enzyme-containing aerosols, a HEPA filter cartridge is preferred. The air supplied respirators deliver air through a supply hose connected to the wearer's face piece. These respirators would be used where higher levels of protection are required. A self-contained breathing apparatus (SCBA) provides air from a cylinder carried by the wearer. This apparatus is primarily used in emergency situations.

Under normal operating conditions in a well-ventilated plant, the routine wearing of respirators is unnecessary for most operations. However, the use of approved respirators is advisable for the following specific circumstances:

- When an accidental spill of concentrated enzyme occurs as a granulate, a slurry, or as a liquid concentrate, or when a significant amount of detergent product containing enzyme is spilled.
- When an operator could be exposed to concentrated enzyme, such as while replacing empty containers, pumping concentrated enzyme liquid from the supply container to a storage tank, or when opening and connecting enzyme totes.
- When an operator or a maintenance employee cleans equipment before maintenance work is undertaken.

- When maintenance employees undertake an emergency repair of units containing concentrated enzyme. If such work is expected to last a long time, then it is advisable that the equipment be cleaned first.

  When air monitoring results are above the exposure guide for enzyme or total detergent aerosol.

3. Eye and Skin Protection

As with most chemicals, eye and skin contact should be avoided when handling enzymes. Protective eye wear and clothing should be worn when there is a potential for eye or skin contact. This may include gloves, safety glasses, goggles, face shield and outer garments such as coveralls. A medical professional should be consulted before using barrier creams.

Protective clothing is particularly important when working with proteolytic enzymes, which are known to cause skin and eye irritation. Operations which may require the use of protective clothing include spill clean up, equipment maintenance and equipment cleaning. Work clothing should not be worn home, but should be changed before leaving work and laundered after each use.

References

American Conference of Governmental Industrial Hygienists (ACGIH). Committee on Industrial Ventilation. Ventilation Manual, 20th edition, 1988. P.O. Box 16153, Lansing, MI 48901, p. 22.

American Industrial Hygiene Association (AIHA). Respiratory Protection — A Manual and Guideline, second edition, 1992, Fairfax, VA.

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VII. AIR MONITORING

Introduction

An air monitoring program should be established to evaluate the potential for employee exposure to airborne enzymes and determine if established control measures are functioning properly or if additional control measures are needed. A monitoring program is more than just taking samples and reporting the values. A successful program requires properly trained individuals conducting the monitoring and analysis of samples, well maintained and calibrated sampling equipment, validated analytical methods, an air sampling plan and data evaluation. The goal of this program is to provide information allowing health and safety professionals to evaluate whether there is adequate employee protection and to identify additional control measures as needed. Suggested control measures are discussed in section VI.

Air Monitoring Personnel

A qualified health and safety professional should oversee the air monitoring program. This individual is responsible for establishing the sampling plan (e.g., sampling frequency, location and sampling time), selection of air monitoring equipment, data evaluation, assessment of the adequacy of control measures and training of individuals collecting the samples. An important aspect of air monitoring is the collection and analysis of samples. The individuals performing these tasks must be adequately trained. The collection of reliable and accurate air sampling data requires training on the following: operation of the sampling equipment, calibration of sampling equipment, data collection (e.g., sample time, flow rate, location, plant operations, employee work practices) and sampling plan. Sample analysis requires training in the use of laboratory techniques and laboratory equipment and the application of enzyme analytical protocols.

Air Sampling

Historically, high volume air sampling equipment has been used for enzyme air sampling. This equipment was necessitated by the sensitivity of the then existing analytical assay. There are currently analytical methods with increased sensitivity which are able to detect lower quantities of enzyme. These more sensitive methods may allow the use of low volume air sampling equipment. The use of high and low volume air sampling pumps is described below.

High volume samplers are commonly used in the detergent industry for collecting area samples. Area sampling is used to obtain information about the presence or absence of enzyme aerosols in those areas where enzyme applications take place, or any other area where concern for enzyme aerosols may exist. The samplers typically operate at 200-850 liters/minute. Manufacturers include Bendix Environmental Research, Sensidyne Incorporated, Graseby GMW, Newton Instruments and Quan-Tec-Air, Inc., among others (see reference section for details). "Teflon" and glass fiber filters are typically used as a collection medium and are generally 11 cm in diameter. High volume sampler manufacturers need to be consulted for method and frequency of calibration. These

samplers require an external power supply for operation. Some of these samplers cannot be used in areas with flammable solvents. Explosion-proof pumps are available for such areas.

Alternatively, low volume sample pumps can be used for personal sampling or area sampling. Low volume sample pumps are made by a variety of vendors such as Gillian Instrument Corporation and SKC Inc. Any pump that can maintain a flow rate of 2-3 liters/minute is suitable for enzyme sampling. Typically, 37 mm glass fiber or "Teflon" filters are used as a collection media. These pumps are easily calibrated with a primary standard. Explosion-proof, low volume pumps are also available.

There are advantages and disadvantages to both types of pumps for sampling enzymes. The high volume pumps have been widely used for many years, and there is a large database of exposure histories and experience with these sampling pumps. The high volume pumps also have the advantage of collecting large volumes of air in a short period of time, which allows the use of sensitive analytical methods with greater detection limits. Flow rate must be recorded at a minimum at the beginning and end of the sampling period. An average flow rate over the sampling period should be calculated; the difference between the initial and final flow rates should be no more than 10%.

On the other hand, low volume pumps are easier to calibrate, can be used to collect personal samples, and do not require an external electrical source for operation. These pumps are considerably lighter and smaller than high volume pumps, which makes them much easier to place for sampling of areas. However, due to the volume of air collected, analytical methods must be very sensitive and longer sampling time is required. Since most of the historical data to establish safe exposure levels for workers have been collected with high volume samplers, there is some uncertainty as to interpreting the data collected from low volume samplers. Only one published study has examined the correlation of low volume and high volume samplers (Bruce et al., 1978).

A source listing for both high and low volume samplers is provided under references at the end of this section.

Analytical Methods

Air samples are collected on filters as described above. It is important to store and transport these filters properly. The analyte is extracted from the filter into aqueous solution prior to analysis. Extraction and analysis are discussed in detail in Bruce et al. (1978) and Rothgeb et al. (1988).

Very briefly, the first step is to determine total airborne dust or mist. This is done by measuring weight gain on the collection filter during sampling and dividing by the air volume sampled. Then, the enzyme level is determined. Two broad categories of analytical methods are available: enzyme activity and immunoassays. Both measure enzyme levels relative to standard solutions prepared from an analytical standard of known activity and protein content. A standard enzyme preparation for analytical purposes should be available from enzyme suppliers.

1. Measurements Based on Enzyme Activity

Enzyme activity is measured by reacting the enzyme with a substrate over a specified time period under controlled conditions of temperature and pH. Resulting chemical product is then measured. Taking proteolytic enzymes as an example, a polypeptide substrate such as dimethyl casein is hydrolyzed by the enzyme to its constituent amino acids. The amino acids are reacted with a second chemical (e.g., trinitrobenzene sulfonic acid) to form a colored complex. Color intensity is measured at an appropriate wavelength and is proportional to active enzyme concentration.

2. Measurements Based on Protein Content of Enzyme (Immunoassay)

Airborne enzyme protein can be determined directly by immunoassays, such as Enzyme Linked Immuno Sorbent Assay (ELISA) techniques. This immunoassay involves complexation of enzyme in a very specific reaction with an antibody specific to that enzyme. The enzyme-antibody complex is subsequently reacted with a second antibody conjugated to a marker. Additional chemicals are reacted with the enzyme complex to produce a color. Color intensity is proportional to enzyme level. Antibodies can be purchased through contract laboratories.

3. Comparisons Between ELISA and Activity Methods

As is evident from Table 1, there are advantages and disadvantages to both methodologies. Typically, these are taken into account by the appropriate professional when determining the best methodologies to use for assessing employee exposure and appropriate preventive measures to be undertaken. While the ELISA is highly sensitive and specific, depending on the availability of the appropriate antibodies, it is time and labor intensive and requires considerable technical skill. The activity method is simple, specific and rapid. Sensitivity is method dependent and thereby variable.

4. Validation of Procedures and Analytical Methods

New users must validate analytical methods in their laboratory. This validation of procedures includes consideration of storage, transportation and recovery efficiencies. Guidance on validation of procedures and analytical methods has been published by the National Institute of Occupational Safety and Health (NIOSH, 1994).

TABLE 1

Comparison Between ELISA and Activity Measurement Methods

Criterion	ELISA	Activity Measurement
Detection	Total specific enzyme protein	Active enzyme only
Sensitivity	High	Moderate to high (method dependent)
Time to Result	Up to 12 hrs	<1 hour
Technical Skill Needed	Considerable to set up Running is simple Needs proper control	Dependent on instrumentation
Assay Process	Labor intensive More steps are involved	Simple sample dilution
Instrumentation	Ranges from simple spectrophotometer to complex systems	Ranges from simple spectrophotometer to complex automated systems
Reagents	Need antibody produced that is specific to enzyme (antigen) (Not all antibodies are commercially available; may need to be developed)	Commercially available
Interference	Minimal	Similar enzymes

Exposure Guides

Exposure guides are an important element in an air monitoring program. These guides provide a reference for exposure levels in a workplace environment that do not adversely affect the health of workers. Air monitoring data can be compared to the established exposure limit to determine if the enzyme level is being controlled sufficiently to protect employee health. Exposure limits based on animal studies and epidemiological data are established by government agencies, consensus groups and by individual employers.

The American Conference of Governmental Industrial Hygienists (ACGIH) has established a threshold limit value (TLV) for *subtilisin* of 60 nanograms/m^3 (where 1 nanogram (ng) is equivalent to 10^{-9} grams) (ACGIH 1994-1995). This TLV is a ceiling value contingent on sampling with a high volume sampler for at least 60 minutes. The *subtilisin* TLV is also expressed as "crystalline active pure enzyme." Other countries have also established an occupational exposure standard (O.E.S.). For example, the United Kingdom O.E.S. is 60 ng/m^3 of pure crystalline *subtilisin*.

Industry strives to have airborne enzyme levels lower than the TLV. Typically, enzyme levels are substantially lower. As an example, some companies have a target level of 15 ng/m^3 for a common protease. Actual results are typically an order of magnitude below that target level. Exposure guides for detergent enzymes other than the common protease can be set by comparing the allergic potential of the enzyme of interest to the allergic potential of a common protease.

Air Sampling Plan

Air sampling includes area and personal sampling. While area sampling is used to evaluate plant control measures, it can also be used to provide an indication of employee exposure. Alternatively, personal sampling is used to evaluate individual employee exposure and characterize exposure by job description.

Seek advice from a qualified safety professional in developing an air sampling plan. The four cornerstones of an air sampling plan are reliability, appropriateness, sufficiency and outcomes.

1. Reliability

Air sampling equipment must be calibrated. Recommended calibration frequency and procedures are contained in the manufacturer's literature. Those responsible for calibration must follow these procedures exactly. Similarly, those taking samples must be trained in air sampling procedures. A qualified health and safety professional is an appropriate training resource.

2. Appropriateness

Areas with highest potential for exposure should be chosen as area sampling locations. Sampling frequency should depend on results. Normally, both total dust and enzyme aerosol are measured in powder detergent manufacturing operations. Only enzyme aerosol is measured in liquid operations. Evaporation of liquid precludes gravimetric measurement of total liquid detergent aerosol.

Appropriate monitoring locations can be selected in each plant by a team including industrial hygiene, medical and manufacturing personnel. As general guidelines, some companies have found monitoring the following locations important:

- Areas where encapsulate or liquid enzyme is added to the detergent formulation. In some factories this requires a number of sampling positions corresponding to the number of dosing units.
- Powder or liquid detergent handling areas, especially where bulk powder or liquid product is not enclosed.
- At the filler head of each packing machine.
- Product recovery areas where damaged products/bottles are reclaimed.

3. Sufficiency

Sampling time should reflect the sensitivity of the analytical method, enzyme levels in the plant, and the air sampling rate of the equipment. Sampling time is typically 60 minutes for area samplers. Ideally, sampling frequency initially should be 2 samples per shift until a minimum of 30 samples is obtained per location. Thereafter, the data at each location should be analyzed statistically and frequency should be adjusted depending on results. A qualified safety professional can advise on specific situations.

There are many methods for analyzing results and setting appropriate frequency. One example uses a statistical concept called Capability Ratio (Cpk) which is illustrated in Figure 1. The Cpk can be expressed as follows:

$$Cpk = \frac{\text{Exposure Guide - Average Value}}{3 \times \text{Standard Deviation}}$$

A target can be set for Cpk. For example, a Cpk of 1.0 means 99.7% of all results are below the exposure guide. Sampling frequency at each location can be based on Cpk with the help of a qualified safety professional. More details on Cpk can be found in references cited at the end of this section.

Other suitable methods may also be used for analyzing results and setting appropriate frequencies.

Figure 1

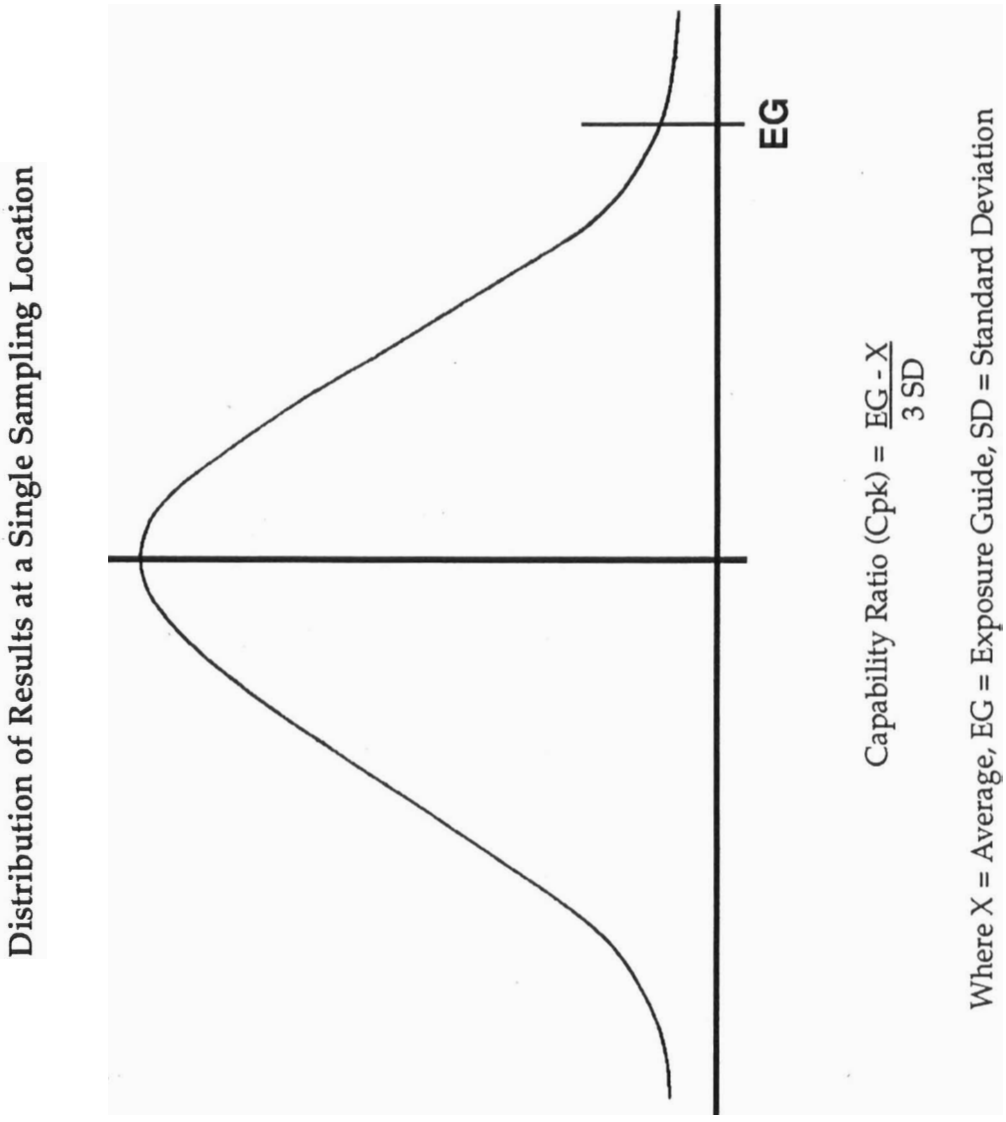
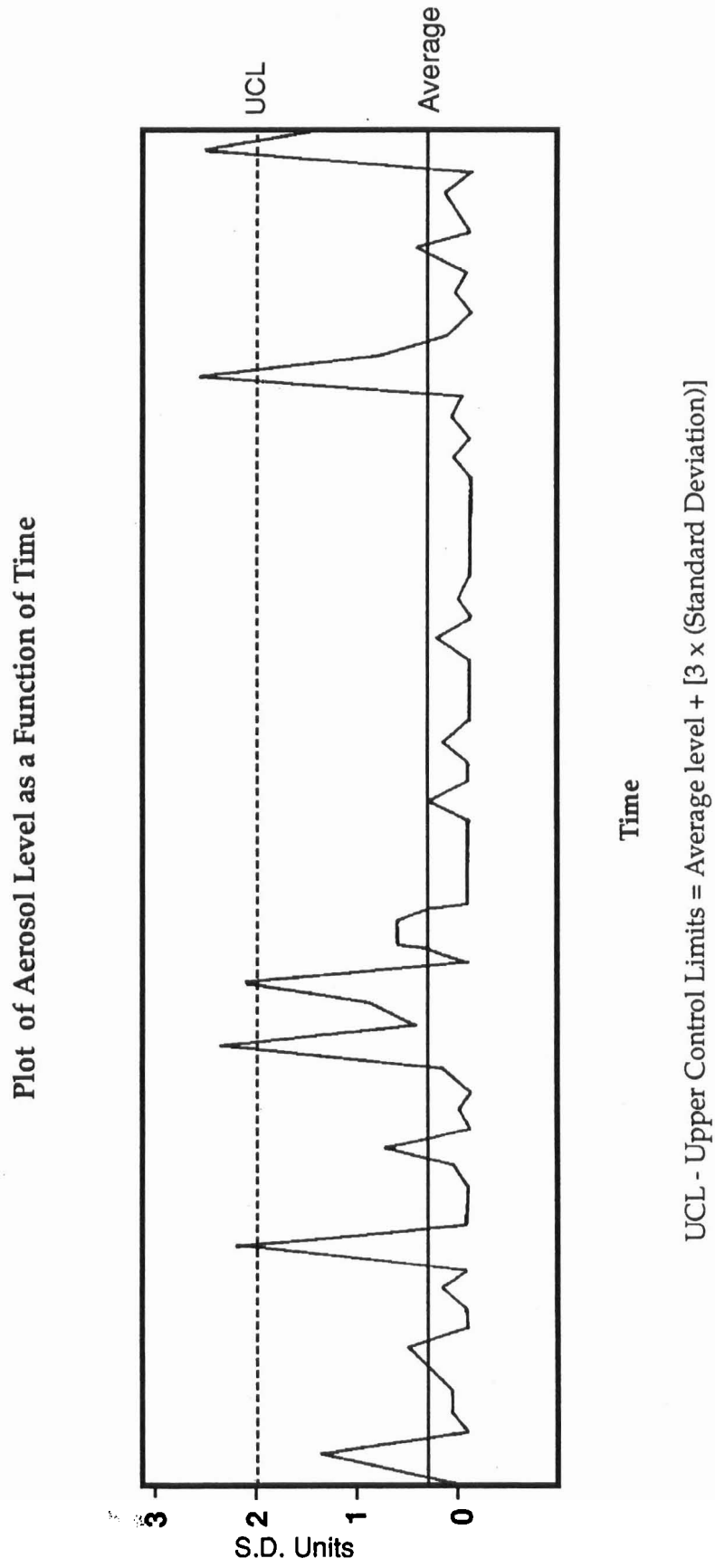

Distribution of Results at a Single Sampling Location
EG
Capability Ratio (Cpk) = EG - X / 3 SD
Where X = Average, EG = Exposure Guide, SD = Standard Deviation

Figure 2


Plot of Aerosol Level as a Function of Time
UCL
Average
3
2
1
0
S.D. Units
Time
UCL - Upper Control Limits = Average level + [3 x (Standard Deviation)]

4. Outcomes

The person taking samples should record any non-routine conditions or behaviors in the area during the sampling period. Sampling results at each location should be plotted as a function of time (Figure 2). In addition to setting an exposure guide discussed earlier, management can also define an upper control limit (UCL) for each location.

5. Upper Control Limit (UCL)

The UCL sets a basis for investigating and improving the system before results exceed the exposure guide. The UCL is usually calculated from the most recent 30 data points. Thus, investigation of results above the UCL helps drive system improvements so that the exposure guide is rarely exceeded.

References

Analysis

Agarwal, M.K., Ingram, J.W., Dunnette, S. and Gleich, G.J. Immunochemical Quantitation of an Airborne Proteolytic Enzyme, Esperase, in a Consumer Products Factory. American Industrial Hygiene Association Journal, 1986, Vol. 47(2), 138-143.

Bruce, C.F., Dunn, E., Brotherton, R., Davies, D.R., Hall, F. and Potts, F.C. Methods of Measuring Biologically Active Enzyme Dusts in the Environmental Air of Detergent Factories. American Occupational Hygiene, 1978, Vol. 21(1), 1-20.

National Institute of Occupational Safety and Health (NIOSH). Manual of Analytical Methods, 4th edition, 1994. Introduction section pp. 8-15 and references. Division of Physical Sciences & Engineering, Cincinnati, OH.

Rothgeb, T.M., Goodlander, B.D., Garrison, P.H. and Smith, L.A. The Raw Material, Finished Product and Dust Pad: Analysis of Detergent Using a Small Synthetic Substrate. JAOCS, 1988, Vol. 65(5), 806-810.

Capability Ratio (Cpk)

Datamyte Handbook Fifth Edition. A Practical Guide to Computerized Data Collection for Statistical Process Control. October, 1992. Datamyte Corporation, 14960 Industrial Road, Minnetonka, MN 55345. Phone: 612-935-7704, fax: 612-935-0018.

Exposure Guide

American Conference of Governmental Industrial Hygienists (ACGIH). TLV Booklet: ACGIH Threshold Limit Values for Chemical Substances, Physical Agents and Biological Exposure Indices, 1994-1995. Technical Affairs Office, Kemper Wood Center, 1330 Kemper Meadow Drive, Cincinnati, OH 45240. Phone: 513-742-2020, fax: 513-742-3355.

Guidance on Validation of Analytical Methods & Selecting Laboratories

National Institute of Occupational Safety and Health (NIOSH). Manual of Analytical Methods, 4th edition, 1994. Introduction section pp. 8-15 and references. Division of Physical Sciences & Engineering, Cincinnati, OH.

Source Listing for High Volume Air Samplers

Bendix Environmental Research. 1390 Market Street, Suite 418, San Francisco, CA 94102. Phone: 415-861-8484.

Graseby GMW. 145 South Miami Avenue, Village of Cleves, OH 45002. Phone: 513-941-2229.

Newton Instruments Company, Ltd., Carr Lane, Hoylake, Wirral, L47 4AY, U.K. Phone: 44-51-632-4780.

Quan-Tec-Air, Inc. 3513 N.W. 7th Street, Rochester, MN 55901. Phone: 507-280-0823.

Sensidyne Incorporated. 1631 Dale Circle F, Dunedin, FL 34698. Phone: 800-451-9444.

Source Listing for Low Volume Air Samplers

Gillian Instrument Corp. 35 St. Fairfield Place, West Caldwell, NJ 07006. Phone: 201-808-3355

SKC Inc. World Headquarters, 334 Valley View Road, RR1 Box 334, Eighty-four, PA 15330-9614. Phone: 412-941-9701.

VIII. KEY AREAS OF PLANT OPERATION

Introduction

There are key areas in detergent manufacturing that require particular attention in the development of an enzyme health and safety program. The health and safety program should address the special case of commissioning an enzyme handling facility. This is an opportunity to ensure that enzymes will be handled safely in the facility. Areas or operations that have a potential for enzyme exposure need particular attention, such as reworking packaged products, cleaning manufacturing areas, container handling and spills.

Commissioning an Enzyme Handling Facility

Before manufacturing enzyme-containing products, the complete production line should be reviewed and tested to ensure that safe operation is maintained. Specific areas for review are listed below. By no means is this list exhaustive; targeted areas will depend on local circumstances. The review should be conducted by management and a safety professional. For more detail, see sections I-VII.

1. **Enzyme Preparation Storage Areas**

   - Are the enzyme preparations isolated from general storage areas?
   - Are there adequate spill containment measures?
   - Is spill control equipment readily available?

2. **Manufacturing Systems**

   - Are ALL conveyors and areas containing enzyme, up to and including the place where the enzyme preparations enter the product stream, enclosed?
   - Are ALL conveyors and areas conveying enzyme-containing product, up to and including the filling heads, enclosed?
   - Is equipment designed to minimize aerosolization?

3. **Ventilation Systems**

   - Is an adequate inward flow (negative pressure) of air maintained at openings where enzymes or enzyme products could be released?
   - Are proper scrubbing/filtration systems used on exhaust air systems?
   - Is air exhausted from the plant in such a way that it does not return to the plant working area via the intake lines?

4. **Monitoring Systems**

- Are air samplers placed in areas where enzyme aerosols might be generated?
- Has an air sampling strategy been established?
- Have the air samplers been calibrated?
- Is analytical support in place to provide timely results?

5. **Work-practice Systems**

- Have all personnel involved in the production, packaging and reclamation of enzyme products been educated in:

  Health Effects of Enzymes
  Control Measures
  Contingency Measures

- Is a medical monitoring program in place?
- Are safe operating practices written for areas with potential enzyme exposure?
- Is appropriate personal protective equipment readily available for all workers?
- Have workers requiring respirators been medically cleared, trained and fit tested in accordance with OSHA standard 29 CFR Subpart I, 1910.134 prior to instituting respirator use?

Reworking Packaged Product

Recovering damaged and out-of-specification products containing enzymes is a process that should be reviewed by a health and safety professional. When recovering products containing enzymes, care must be taken to minimize the production of respirable aerosols and to limit skin contact with the product.

The reclamation area should be dedicated and isolated. Packaged product must be opened and emptied in a well-ventilated area, preferably one that is enclosed and served by local exhaust ventilation. The inward velocity of air should be sufficient to ensure that no aerosol escapes. The recovery operation should be designed to avoid the formation of aerosols. Health and safety professionals should advise on the use of appropriate personal protective equipment. Respirators should not be necessary unless the above measures do not adequately control the exposure. In all cases, an air sampler should be placed adjacent to the work area to monitor the maintenance of safe operating conditions.

Cleaning Manufacturing Areas Involved in Enzyme Production/Storage

When cleaning these areas, workers should use the appropriate personal protective equipment. Cleaning must be done in such a way as to prevent aerosol generation. The area should be cleaned thoroughly, followed by water rinses. Rinse water should be handled and discharged in the appropriate manner in order to ensure compliance with federal, state and local laws. Consult your health and safety professional for advice on control measures to prevent exposure.

Disposal of Enzyme Preparations and Their Containers

Disposal of unwanted enzyme preparations should be in compliance with federal, state and local laws. Consult your enzyme supplier to determine the most appropriate means of discarding unwanted enzyme preparations.

All empty containers should be treated as if they contained enzyme. Workers should use the appropriate personal protective equipment when cleaning these containers. Containers which are not returned to the supplier should be handled with caution to prevent the formation of aerosols. Drums should be rinsed and disposed of in compliance with federal, state and local laws. Consult a qualified safety professional on control measures to prevent exposure.

Enzyme Usage and Storage Reporting Requirements

The manufacturer must know all local and federal regulations. An example is the Emergency Planning and Community Right-to-Know Act (EPCRA) which was enacted as Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). The purpose of this Act is to provide citizens with information about the hazardous chemicals present in their communities. U.S. EPA has published a list of "extremely hazardous substances" and "hazardous substances" and has established a threshold planning quantity for each. Certain reporting requirements are triggered when a facility uses or stores 10,000 pounds of a hazardous substance, or 500 pounds of an extremely hazardous substance. A facility owner or operator must be aware of the presence of such substances at a facility and make the required notifications.

Spills

Care should be taken when handling enzyme preparation spills to prevent the generation of aerosols. Workers should use appropriate personal protective equipment as recommended by a qualified safety professional. Measures should be taken to contain all spills. Vacuums using high efficiency filters or a dedicated central vacuum system are preferred. At no time should spills be swept, brushed or dispersed by air blowing or high pressure water jets. After the spill is collected, the area should be gently washed using cold, low pressure water or water-spray portable vacuum cleaners. Consult a qualified health and safety professional on spill clean-up for procedures tailored to particular industrial settings.

For certain spills, federal, state and local laws may require that notification be given. For example, under the Comprehensive Environmental Response, Cleanup, and Liability Act (CERCLA) 42 U.S.C. §960 et seq, a facility owner or operator must notify the National Response Center (NRC) (Tel: 800-424-8802) immediately upon the release of a "reportable quantity" of a "hazardous substance" if such reportable quantity is released within a 24-hour period. CERCLA regulations apply to releases of hazardous substances to the land, air or water, or any combination of environmental media. Hazardous substances spilled within buildings or structures are not reportable unless a "reportable quantity" leaves the building or structure. The statutory definition for "hazardous substance" includes substances listed in the Clean Water Act, 33 U.S.C. §1321 (b)(2)(A); CERCLA; the Solid Waste Disposal Act 42 U.S.C. §6921; the Clean Air Act 42 U.S.C. §7412; and the Toxic Substances Control Act § 7, 15, U.S.C. §2606. Additionally, the facility owner or operator should ensure that spill notification provisions which may be contained within a given operating permit issued to the facility have been met.

References

Occupational Safety and Health Administration (OSHA), 29 CFR 1910.134 (Respiratory Protection).

Clean Water Act, 33 U.S.C. §132(b)(2)(A).

The Solid Waste Disposal Act, 42 U.S.C. §6921.

The Clean Air Act, 42 U.S.C. §7412.

The Toxic Substances Control Act , §7, 15 U.S.C. §2606.

The Comprehensive Environmental Response, Cleanup and Liability Act, 42 U.S.C. §960.

The Emergency Planning and Community Right-to-Know Act, Title III, SARA 1986.

IX. MEDICAL MONITORING PROGRAM FOR ENZYME WORKERS

This section discusses monitoring of employees potentially exposed to enzymes at their workplace. It is intended for use by companies producing enzyme-containing cleaning product formulations. However, it may also be applicable to other industries using enzyme technology.

The intent is to assess and monitor the health of employees working with enzymes. A program should be designed to survey employee health to ensure that any adverse health effects are uncovered and dealt with early. Occupational health and safety stewardship of enzyme technology is important to prevent health allegations that could erode public trust in the cleaning products industry.

Enzymes can cause sensitization and, in some cases, symptoms in susceptible, exposed individuals. If enough enzyme is inhaled, the body will begin to recognize the enzyme as a foreign material and produce allergic antibodies. Once allergic antibodies are produced, the individual is said to be sensitized. Sensitization by itself is not a disease. In individuals who have become sensitized, further breathing of high levels of enzyme dust or aerosol can trigger symptoms ranging from allergy symptoms such as watery eyes, runny nose and scratchy throat to occupational asthma. A bibliography is enclosed as Attachment 3 for those who may wish to further explore the health effects of enzymes.

Medical Monitoring of Enzyme Workers — Notes for Medical Practitioners

For a new employee or an employee transferring to enzyme work, the following may be considered:

1. Medical History. Obtain a medical history of the employee. Specific reference should be made to any history of allergies, asthma, eczema, smoking, previous chest disease and medication use.

2. Respiratory Questionnaire. Have the employee complete a respiratory questionnaire. Examples are included in Attachment 2.

3. Medical Examination. On the basis of the medical history or responses to the respiratory questionnaire, the medical examiner may decide to conduct a physical examination.

4. Baseline Pulmonary Function Test (PFT). A PFT should be done on all employees before they begin working with enzymes so that a pulmonary function baseline can be established against which future PFT results can be compared.

5. Baseline Determination of Enzyme Sensitivity. A baseline determination of enzyme sensitivity may be made using either a skin prick test of enzyme(s) that the employee will be exposed to or a blood test (e.g., RAST) to determine the level of antibody against the specific enzyme allergen that is present in the blood. If a skin test is

performed, a negative (saline) and positive (histamine) control should be used as a reference for the enzyme antigen.

6. Skin Prick Test for common allergens. A skin prick test for common allergens may help determine the atopy of the individual.

Routine Medical Monitoring for Employees Working With Enzymes

1. Routine monitoring should be conducted annually in a stable enzyme environment. In non-stable situations, such as when new enzymes are first introduced, process changes occur, or when there is an increase in symptoms among workers, monitoring should be more frequent (e.g., at six months).

2. Key Components of Routine Medical Monitoring:

   - Reassessment of lung function (Pulmonary Function Test).
   - Repeat enzyme sensitivity testing. This includes follow-ups on baseline skin prick test or RAST test, as appropriate.
   - Smoking history.
   - Any relevant history of symptoms, particularly upper or lower respiratory illness since a previous examination.

Employees With Respiratory Symptoms

Employees should inform management of the presence of any respiratory symptoms. These employees should be medically evaluated promptly to determine if the enzymes may be the cause of the symptoms. This normally requires removing these employees from the enzyme environment until a diagnosis is made.

Outcomes and Actions From Medical Monitoring

1. Baseline Testing of New or Transferred Employees Working With Enzymes for the First Time

A corporate policy dealing with workplace accommodations should be in place. This involves classifying workers as:

- Fit for enzyme work.
- Fit with restrictions, i.e., should avoid areas of the plant where there is a potential for high exposure.
- Unfit for enzyme work.

Employees with a history of severe asthma, chronic obstructive lung disease, other severe chest disease or considerable reduction of lung function as determined in a PFT should be counseled on the risks of working in areas with potential enzyme exposure.

2. Routine Periodic Reviews of Employees Working With Enzymes

- Those with negative findings may continue to work and be monitored on a regular basis and work without restrictions.
- Those who are symptom-free and have no change in pulmonary function, but show sensitization by either skin test conversion or positive RAST test can continue to work in enzyme areas. However, they must be advised to inform the company's medical examiner of any upper or lower respiratory symptoms that may develop.
- With symptomatic employees, if a non-enzyme cause cannot be determined or diagnosed, the employee should be removed from areas with enzyme exposure pending skin prick or RAST test results. If they are sensitized to the enzyme, they should be counseled on the risks of working in areas with potential enzyme exposure. The employee may be restricted from working in the enzyme areas.

Testing

1. Respiratory Questionnaire

A set of questions can be administered at the time of routine spirometry testing. Respiratory system review questions including breathing symptoms, smoking, occupational dust exposure and known lung diseases and injuries are asked. Examples are included in Attachment 2.

2. Spirometry

Spirometry is a screening method for measuring lung function. It is commonly used in a variety of occupational health programs including those related to respiratory sensitizers such as enzymes. Significant changes in lung volumes are used to interpret functional changes in the pulmonary system and to detect the presence or absence of pulmonary disease. Lung volumes are measured in metric units, cubic centimeters of air, or liters per second (L/sec). A spirogram is a recording which graphically represents various pulmonary functions.

Spirometric values are often expressed along with their predicted values, allowing comparison of actual test values to a 'normal' group. Expected values, referred to as predicted normal values, for various lung volumes and flow rates are derived from healthy populations. When available, comparison to an individual's own prior spirogram best reflects recent lung function changes. Lung function can be affected by numerous non-enzyme related conditions. These must be considered when evaluating results of spirometry tests.

The nurse or other certified personnel performing spirometry and administering pulmonary questionnaires must be properly trained, e.g., have successfully completed a NIOSH approved pulmonary function course.

Pulmonary function testing is available at community occupational health clinics or hospitals. These clinics or hospitals would be the preferred testing site for facilities or organizations that do not have in-house capability for testing. Some clinics provide mobile service and will do the testing on site. In locations where there is no occupational health service available, this test may be performed by a local pulmonary specialist or at the outpatient department of most hospitals.

Calculated spirometry pulmonary measures along with abbreviated definitions of the terms follow:

A] Calculate: $\frac{\text{Observed (i.e., tested) } FEV_1}{\text{Predicted (from table) } FEV_1} = \frac{?\ \%}{}$ (Normal = 75% or greater)

B] Calculate: $\frac{\text{Observed FVC}}{\text{Predicted FVC}} = \frac{?\ \%}{}$ (Normal = 80% or greater)

C] Calculate the Ratio: $\frac{\text{Observed } FEV_1}{\text{Observed FVC}} = \frac{?\ \%}{}$ (Normal = 70% or greater)

where the terms have the following definitions:

FEV_1: Forced Expiratory Volume in one second, a spirometric volume measurement of air exhaled during the first second of the FVC.

FVC: A vital capacity representing maximal inspiration and expiration.

FEV_1/FVC%: Forced Expiratory Volume in one second expressed as a percentage of the Forced Vital Capacity. A spirometric calculated value useful in assessing airway obstruction.

When an employee's results fall below normal in A, B or C, the case should be reviewed by a medical examiner to determine fitness of the individual to work in an enzyme exposure area.

Other useful definitions are:

PEFR: Peak Expiratory Flow Rate is a physiological measurement of lung function that can be carried out before, during and after work shifts to determine the relationship between possible reduction of lung function and occupational exposures. These are done by the employee using a hand-held portable device.

Obstructive Lung Disease: Lung conditions that inhibit air exiting and entering the lungs. This can include reversible obstruction such as asthma and non-reversible chronic obstructive pulmonary diseases, e.g., emphysema.

3. Skin Prick Test

The value of skin tests in the diagnosis of allergic conditions was first described over a century ago by the English physician, Charles Blackley. Skin tests are used by health professionals for the identification of causal allergens in symptomatic individuals, monitoring changes in sensitivities to specific allergens (e.g., enzymes), and screening for asymptomatic, atopic individuals. Specifically, a skin prick test program is used in the detergent industry to detect sensitization to enzymes (i.e., the presence of specific antibodies).

Skin prick testing should be performed by a qualified health professional with specific training in this procedure. Details of the test are referenced below. Enzyme suppliers should be contacted for information on skin prick solutions.

No anaphylactic (severe allergic) reactions have been reported to skin prick tests with enzyme solutions. It is, however, recommended that the testing facility have a 1:1000 solution of adrenalin available and ready for use. Also, a fresh needle must be used for each skin prick test.

An example summary of a skin prick test procedure follows:

The anterior surface of the forearm is used. One drop of the appropriate test solution (antigen) is placed beside a marked (felt tipped pen) area of the arm. The tip of a 25 or 26 gauge needle is passed through the drop and inserted into the skin at an angle so that the skin may be lifted on the bevel. The needle is withdrawn and the excess solution is wiped off with a paper tissue. Each solution is pricked into the skin only once and a new needle is used for each skin test. A prick test with sterile saline is used as a negative control. An example of a positive control is histamine phosphate 1:1000.

With the skin prick test, blood should not appear at the prick test site. If blood appears, repeat the test at another site. A wheal is a raised, red area at the site of the test. A flare is surrounding redness (erythema). Scoring is determined 15 minutes after pricking and is compared against a negative control.

A positive reading is:

- a wheal of 3 mm diameter or larger with a surrounding flare or
- a wheal (with flare) that is 3 mm larger than a wheal using a negative control.

Each wheal and flare should be measured in millimeters and the measurement should be recorded as the mean of two crossing measurements made at a 90 degree angle. Results should be entered into records kept on each subject.

Recent use of antihistamines may modify skin reactions. Tests on immuno-compromised people may not accurately detect sensitivity.

More detailed descriptions for skin prick testing may be found in the following references:

Brown, H.M., Su, S. and Thatney, N. Prick Testing for Allergens. Clinical Allergy, 1981, Vol. 11, 95, 98.

Nelson, H.S., Rosloniec, D.M., McCall, L.I. and Ikle, D. Comparative Performance of Five Commercial Prick Skin Test Devices. J. Allergy Clinical Immunology, 1993, Vol. 92, 750.

Norman, P.S. Skin Testing. Manual of Clinical Laboratory Immunology, 4th edition, 1992. Vol. 100, 685-688.

Pepys, J. Skin Testing. British Journal of Hospital Medicine, October, 1975, 912-917.

4. RAST Test

RAST (RadioAllergoSorbent Test) is a blood test in which the actual amount of circulatory enzyme-specific IgE in the blood is measured. The enzyme being tested is bound to cellulose particles. Blood serum from a worker is then added to this coupled enzyme/cellulose complex. Any IgE molecules in the serum of a sensitized person will specifically bind to the enzyme to yield a 3-layer complex. Anti-IgE radiolabeled materials are then added which react on a one-to-one basis with each of the IgE molecules absorbed in the complex. The end result is a four-layered sandwich in which radioactivity is incorporated on a quantitative basis for each of the IgE molecules that were in the blood sample. By counting the radioactivity, the amount of enzyme specific IgE can be measured.

More detailed descriptions for RAST testing may be found in the following references:

Dor, P.J., Agarwal, M.K., Gleich, M.C., Welsh, P.W., Dunnette, S.L., Adolphson, C.R. and Gleich, G.J. Detection of Antibodies to Proteases Used in Laundry Detergent by the Radioallergo Sorbent Test. Journal of Allergy and Clinical Immunology, 1986, Vol. 78 (5), 877.

Sarlo, K., Clark, E.D., Ryan, C.A. and Bernstein, D.I. ELISA for Human IgE Antibody to Subtilisin A (Alcalase): Correlation with RAST and Skin Tests with Occupationally Exposed Individuals. Journal of Allergy and Clinical Immunology, 1990, Vol. 86(3), 393.

Turkeltaub, P.C., Rastogi, S.C., Baer, H., Anderson, M.C. and Norman, P.S. A Standardized Quantitative Skin-Test Assay of Allergen Potency and Stability: Studies on the Allergen Dose-Response Curve and Effect of Wheal, Erythema, and Patient Selection on Assay Results. J. Allergy and Clinical Immunology, 1992, Vol.70 (5), 343-352.

5. Peak Expiratory Flow Rate (PEFR)

This is one measure for assessing occupational asthma. Measurements are recorded on a portable, hand-held peak flow meter. Employees are instructed to record continuous readings before, during and after working. A qualified pulmonary specialist or occupational physician can interpret results and help determine if the employee's respiratory problem is related to workplace exposures.

Diagnosis

1. Upper Respiratory Symptoms

Diagnosis of upper respiratory symptoms, such as enzyme rhinitis, is determined by medical history and repeated observations of symptoms related to exposure and followed by disappearance of symptoms after one or two days removal from exposure. This can be accomplished by a self-administered symptom scoring sheet on which indications of symptoms, their character and working hours are recorded on all days during a period of more than 3 weeks. If upper respiratory symptoms are suspected, the employee should be removed until a definite diagnosis is made. If a corporate policy exists, the employee may be restricted from working in the enzyme area.

2. Occupational (Enzyme) Asthma

Diagnosis of enzyme asthma is determined by sensitization, clinical manifestation and pulmonary function testing as detailed below. All diagnostic criteria must be fulfilled in order to be diagnosed with occupational asthma. Until a definitive diagnosis is made, employees suspected of having occupational asthma must be removed from exposure.

Occupational Asthma Diagnosis:

- Sensitization should be demonstrated by either a positive skin test or RAST test. In rare cases where determining sensitization is difficult, both skin prick and RAST tests can be performed.
- Clinical symptoms such as chest congestion, coughing, shortness of breath, wheezing, etc., should be documented.

- Pulmonary function changes of the following nature are indicative of occupational asthma:

  — A drop in FEV_1 of 15% or more from the subject's normal (or baseline) value.
  — A pattern of peak flow measurements relating change in lung function to occupational exposure.

In difficult cases, referral to specialized pulmonary centers or hospitals may be necessary. These facilities can perform a methacholine challenge test which may help in the definitive diagnosis of asthma. (NOTE: This is a very precise test for establishing a diagnosis of asthma. Occupational asthma is a combined diagnosis which requires the demonstration of specific sensitization to enzyme or another allergen in the work place and the presence of asthma symptoms related to work exposure.)

ATTACHMENT 1

Ventilation Principles

A. Introduction

Local exhaust ventilation (LEV) is suggested over dilution ventilation (defined in section 3 of this attachment) because it intercepts the contaminant as soon as it is generated so that it is removed from the workplace before it can be inhaled. Dilution ventilation, on the other hand, lowers the concentration of the contaminant in the workplace, but it does not totally eliminate exposure as can LEV.

In plants producing powder detergent, LEV may be supplemented where necessary by a dilution system to ensure that total dust levels are kept low. In plants producing liquid products, LEV has been found sufficient to control aerosols.

B. Local Exhaust Ventilation

1. Capture Velocity/Face Velocity

The capture velocity is an air velocity produced by the local exhaust ventilation system which is necessary to prevent escape of aerosols into the workplace atmosphere. It is measured at any point close to hood's edge (or shroud). Equipment handling detergents that is liable to allow the escape of aerosol is maintained at a negative pressure to ensure an inward air flow greater than the capture velocity at all openings. A qualified ventilation engineer needs to be consulted.

Local exhaust ventilation is applied in the following locations in detergent plants:

a. Bulk Enzyme Container Handling

The cleaning products industry uses ventilation systems to maintain face velocities at door openings into which containers are placed for discharge into the dosing system. As this is the key location in the plant, it is essential that the ventilation system operate efficiently. Ventilation systems are equipped with dry or wet high efficiency filters.

High efficiency filters are filters that are 99.97% efficient when challenged with a 0.3 μm dioctyl phthalate (DOP) particle. Wet systems are noisier and more expensive to operate than dry systems. High efficiency dry filters are smaller and can be dedicated to the equipment being exhausted. These filters require routine maintenance which must be carried out by operators wearing approved personal protective equipment.

b. Enzyme Dosing Equipment

Local exhaust ventilation is also applied to units used in dosing liquid or granule enzymes to produce liquid or powder detergent formulations. If possible, the weigh belt or metering device should be totally enclosed. The air volume extracted from the unit should be sufficient to maintain an

inward velocity at the discharge end of the weighing device, and at removable doors which provide access for cleaning. Access doors should be constructed so that they are easily removed and replaced. Unless doors are easily replaced, it may be found that they tend to be permanently removed, which will prevent proper operation of the ventilation equipment.

c. Filling Heads

Filling heads of liquid and powder packing machines should be enclosed except for a minimum area required to ensure adequate air inflow. Access doors are to be fitted so that engineering adjustments can be made. Dedicated filter units should be used to ensure that face air velocity at the point of package entry and exit from the unit is sufficiently negative to prevent enzyme release into the ambient environment.

Liquid filling machines can be similarly enclosed with air volume extracted at a rate sufficient to maintain appropriate velocities. However, local ventilation at each filling nozzle is preferred, because it allows for easier access to the remainder of the machine.

C. Dilution Ventilation

Dilution ventilation refers to dilution of contaminated air with uncontaminated air in a general area, room or building for the purpose of health hazard control (ACGIH, 1988). Depending on the design of the plant, dilution ventilation may be required to supplement local ventilation in areas where encapsulates are handled and in the packing room. In areas where enzyme containers are handled, dilution ventilation may be used to prevent stagnation and minimize the effect of any accidental spills that could occur. Spills in this area must be vacuumed by either a dedicated central vacuum system or a vacuum using high efficiency filters.

In the packing room, dilution ventilation may be installed if natural ventilation is believed to be inadequate. It is not recommended that dilution ventilation be used as a substitute for LEV at the filling heads. A specialist should be consulted before any dilution ventilation scheme is installed in order to prevent over or under-design. However, the system design needs to take into account local conditions when dilution ventilation is required. The position of windows or access doors to other parts of the factory or to the outside needs to be taken into account because air flows through such openings can significantly affect the efficiency of the system.

Consult a qualified health and safety professional for advice on air recirculation systems; in particular, the positioning and maintenance of high efficiency filters and system testing.

All extracted air likely to contain dust should be routed via the appropriate filtering system and the point of exhaust into the atmosphere chosen so that the air cannot return into the working environment. This is particularly important in the case of air extracted from areas where concentrated enzymes are handled. For general use, reverse jet filters are recommended.

Manufacturer recommendations should be adhered to regarding the frequency with which filters are cleaned or changed. Federal, state and local air exhaust permitting requirements should be considered.

After commissioning, air velocities and pressures should be routinely recorded to provide standard performance data for future reference.

- Determine the need for maintenance and detect any defective operation.
- Ensure safe practices for maintenance.
- Indicate the responsible party for maintenance.

Maintaining proper ventilation requires that:

- ventilation systems are visually checked at a frequency recommended by the manufacturer, and
- LEV systems installed to confine potential enzyme aerosol release are examined periodically, depending on results generated from air flow and pressure measurements.

References

American Conference of Governmental Industrial Hygienists (ACGIH). Committee on Industrial Ventilation. Ventilation Manual, 20th edition, 1988. P.O. Box 16153, Lansing, MI 48901, p. 22.

ATTACHMENT 2

Respiratory Questionnaire

Example 1

A Basic Medical Questionnaire

	NO	YES	DETAILS
1. Do you usually cough?	___	___	_____
2. Do you bring up phlegm (sputum)?	___	___	_____
3. Are you troubled by shortness of breath?	___	___	_____
4. Do you ever have a wheeze or a whistling sound in your chest?	___	___	_____
5. Have you ever suffered from asthma, bronchitis, or any chest illness or condition?	___	___	_____
6. Have you ever had treatment for your chest (tablets, inhalers) even as a child?	___	___	_____
7. In the last three years, have you had any chest illness lasting more than a week?	___	___	_____
8. Have you ever had eczema (even as a child)?	___	___	_____
9. Have you ever had hay fever and/or episodes of sneezing, itchy eyes, runny nose?	___	___	_____
10. Have you ever had an allergy to anything?	___	___	_____
11. Have you ever been admitted to a hospital?	___	___	_____

Smoking habits

12. Do you smoke? If NO, answer Question 13a _____

If YES, answer Question 13b _____

13a. Have you ever smoked?	___	___	_____
13b. How much do you smoke?	___	___	_____

Employee Signature: _____ Date: _____

Respiratory Questionnaire

Example 2

A Patient Pulmonary Profile

Test ID #: 0000002663

Health Services Department

Personal Information

Name:		Age:	62 yrs
SSN #, Sup ID:	003646357	Height:	169.0 cm./66.5 in.
Sex, Race:	Female, White	Weight:	77 kg./169 lbs.

Pulmonary Job Description

Location:	TORONTO
Department:	DRY GOODS
Shift:	DAYS
Job Classification:	CLERK

Pulmonary Test Information

Calibration Time:	Thu Aug. 25, 1994, 7:49 a.m.
Calibration Volume:	3.000 Liters
Spirometer Temperature:	23.0 C
Barometric Pressure:	750g
BTPS Scale Factor:	1.085
End of Test Criteria:	3.0 Seconds
MWS Serial Number:	MI00238
MWS Software Version:	DOS 5.565-09/29/92 094:59 p.m.

Example 2 (cont.)

Basic Questions

1 Cough _____Y
3 months this year ____Y
# of years _____12
2 Phlegm _____Y
3 months this year_____ Y
# of years _____Y
3 Chest Tightness _____Y
4 Shortness of Breath ____Y
While Washing
5 Wheeze or Whistle ____Y
# of years _____Y
6 Asthma _____Y
Age started_____12
Medications _____Y
7 Pneumonia_____Y
8 Tuberculosis _____Y
9 Heart Disease_____Y
10 Chest Surgery _____Y
11 Abnormal X-Ray _____Y
Date_____12/12/94
12 Cigarettes _____C
Years smoked _____50
Quit past 12 mo _____?
Years stopped _____0
Packs per day _____1
13 Pipe_____C
14 Cigar _____C
15 Chewing Tobacco_____C
Years used _____50
Quit past 12 mo _____?
Years stopped _____0
Times per day _____1.2
16 Snuff _____C
Years used_____50
Quit past 12 mo_____?
Years stopped _____0
Times per day _____1.2
17 Occupational Exp_____Y
Foundry,Mine,Quarry__Y
# of years _____2
Sandblasting_____Y
# of years _____12
Asbestos _____Y
# of years _____12
Textile Mill _____Y
# of years _____12
Irritant Chemicals ____Y
# of years _____12
Work Related Sym ____Y
18 Allergy Issue_____Y

Allergy Questions

19 Hay Fever _____Y
This year _____Y
20 Allergies_____Y
Diagnosed Allergies __Y
RATS
SNAKES
DOGS
CAT
Skin Test _____Y
Positive _____Y
21 Allergy symptoms ____Y
Worse on weekends____Y
Worse at week start ____Y
Worse at week end ____Y
Constant all seasons __Y
Constant all day _____Y
22 Sore throat _____Y
Scratchy throat _____Y
Stuffy nose _____Y
Wheezing _____ Y
Sneezing attacks _____Y
Runny nose _____Y
Itchy/watery eyes ____Y
Post-nasal drip_____Y
All year around _____Y
Spring _____?
Summer_____?
Fall _____?
Winter _____?
23 Eczema _____Y
Eczema in skin folds __Y
Dry skin_____Y
Infectious illnesses ____Y
24 Family allergies _____Y
25 Family eczema _____Y
26 Hay fever medication___Y
27 Anti-histamines_____Y
28 Cortisone _____Y
29 Aspirin/muscle relax __Y
30 Allergy shots_____Y

Respiratory Questions

31 Respirator Cert _____Y
32 Collapsed Lung _____Y
33 Seizures,Epilepsy _____Y
34 Diabetes _____Y
35 Claustrophobia _____Y
36 Back or arthritis_____Y

Example 2 (cont.)

The Predicted Norms were established by
Crapo, R.O.; Morris, A.H.; Gardner, R.M.
Reference spirometric values using techniques & equipment that meet ATS recommendations
American Review of Respiratory Disease, 1981, Vol. 123(6), 659.

Test Time: Thu Aug 25, 1994 9:42 AM
Values

ID#: 0000002663

	Units (BTPS)	Test PRED	OBSERVED	% PRED
FEV_1	Liters	2.63	2.22	84
FVC	Liters	3.38	2.71	80
FEV_1/FVC	%	78	82	105
FEF(25-75)	Liters/Second	2.44	2.60	107

Test Quality: GOOD

Computer Interpretation

Volumes and flow rates for the forced expiration are normal. Tests meet repeatability criteria.

Observations, Comments and Interpretations

Report printed: Thu August 25, 1994 9:49 AM
Attending Physician:
Operator's Name:

Signature

ATTACHMENT 3

Medical Monitoring Bibliography

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GLOSSARY

Aerosol - Small airborne solid or liquid particles suspended in air, i.e., dust or mist.

Air Purifying Respirators - Respirators with an air purifying filter or cartridge to capture airborne contaminants.

Air Supplied Respirators - Respirators that deliver air from an external source to the breathing zone.

Allergy - An immunological condition acquired through exposure to a material (allergen) which results in an enhanced reaction to the material upon re-exposure. Allergies to enzymes, as with other proteins, are mediated by antibodies. Symptoms of enzyme allergies may include any or a combination of the following: sneezing, nasal or sinus congestion, coughing, watery and itchy eyes or nose, hoarseness or shortness of breath.

Amylase - A class of enzymes that speed up the breakdown of the chemical bonds between the connecting sugar molecules in starch.

Antibody - Specialized proteins of the immune system that recognize specific allergens and trigger an immune response.

Antigen - A protein or a carbohydrate substance capable of eliciting an immune response.

Antiserum - Blood serum containing antibodies.

Asthma - A medical condition in which the airways of the lung narrow in response to irritation, allergy or other stimulus. Symptoms may include shortness of breath, wheezing and labored coughing.

Atopic - A tendency or an individual with the tendency to become sensitized or hypersensitive more easily than others and to develop allergies, such as hay fever, more readily after exposure to an antigen.

Biodegradable - A substance or compound capable of decomposing through a natural biological process in the environment.

Capability Ratio (Cpk) - A mathematical formula reflecting the difference between a mean value and a fixed limit. It also takes into account the distribution of results around the mean.

Cellulose - A chemical compound found in plants and made up of repeating chains of sugar molecules. It is a major component of plants.

Dilution Ventilation - Refers to the dilution of contaminated air with uncontaminated air in a general area, room or a building for the purpose of health hazard control.

Dioctyl Phthalate (DOP) - An oily particle commonly used for quantitative fit testing of personal protective equipment and filter testing.

ELISA (Enzyme Linked Immuno Sorbent Assay) - A sensitive laboratory method for detecting serum antibodies resulting from antigen exposure.

Enzyme - A large catalytic protein molecule. Enzymes are present in all living organisms. They speed up the chemical reactions necessary to sustain life. Two of their essential functions are in the conversion of food to energy and conversion of food to other new cell material.

Enzyme Activity Test - An enzyme reacts with a substrate for a defined time under controlled conditions of temperature and pH. Reaction products form a colored complex with a color development reactant. Enzyme activity of an unknown solution is determined relative to standard solutions.

Enzyme Rhinitis - An inflammation of the nasal mucosal membrane due to exposure to enzymes.

Enzyme Technical Association (ETA) - A trade association of companies which manufacture and market enzyme preparations in the United States.

FEV_1 - Forced Expiratory Volume in one second. A spirometric volume measurement of air exhaled during the first second of the FVC.

FEV_1/FVC - Forced Expiratory Volume in one second expressed as a percentage of the Forced Vital Capacity. A spirometric calculated value useful in assessing airway obstruction.

FVC - Forced Vital Capacity. A maneuver performed with a maximally forced expiratory effort from maximal inspiration.

Granulated Enzymes - Enzymes formulated in a non-dusting solid form, usually with a protective coating, typically between 200 and 100 microns in diameter. There are many different technologies available for granulating enzymes, including high shear granulation, extrusion/marmerization, spray-coating and prilling.

High Efficiency Particulate Air (HEPA) Filter - According to NIOSH, a high efficiency filter is one that is at least 99.97% efficient when challenged with a 0.3 µm dioctyl phthalate particle.

Histamine - A chemical released from specialized cells in the body that produces the symptoms of an allergic reaction.

High Efficiency Filter/Scrubber - a filter that retains 99.97% of dioctyl phthalate with a particle size of 0.3 µm.

Immunoassay - An *in vitro* assay detecting serum antibodies resulting from exposure to antigens.

Irritant - A substance capable of producing irritation or inflammation as a result of its contact with living tissue. Unlike allergens, the response is not dependent on the immune system.

Local Exhaust Ventilation (LEV) - A system for capturing and removing airborne contaminants at or near the workplace where they are produced. The system usually includes an enclosure, ductwork, an air cleaning device and a fan.

Lipase - A class of enzymes that speed up the breakdown of fats.

Lipid - A class of chemical compounds, including fats and oils, found in plant and animal cells.

NIOSH (National Institute of Occupational Safety and Health) - Part of the U.S. Department of Public Health Service, U.S. Department of Health and Human Services, this agency was established as the research counterpart to the Occupational Safety and Health Administration. NIOSH serves to test and certify respirators, recommend occupational exposure limits, and conduct occupational safety and health investigations and research.

Obstructive Lung Disease - Lung conditions that inhibit air exiting and entering the lungs. Includes reversible obstruction such as asthma and chronic obstructive pulmonary diseases such as emphysema.

Occupational Asthma (Enzyme Asthma) - Asthma produced by workplace conditions. Enzyme asthma is a specific type of occupational asthma, in which the asthmatic response is triggered in sensitized persons by breathing an excessively high concentration of enzymes.

OSHA (Occupational Safety and Health Administration) - Part of the U.S. Department of Labor, this agency was established to promulgate and enforce workplace health and safety standards.

Prilled Enzymes - One form of granulated enzymes, based on encapsulating the enzyme (from powder or concentrate) in a matrix of waxy binder and inactive fillers, and spraying it into spherical beads in a prilling tower. The waxy binder is, e.g., an ethoxylated fatty alcohol.

Peak Expiratory Flow Rate (PEF) - A measurement that helps in the diagnosis of occupational asthma. These measurements are recorded on a flow portable, hand-held peak flow meter. Employees are instructed to record continuous readings during and after working.

Peptide Bonds - Chemical bonds that attach amino acids together in proteins.

Personal Protective Equipment (PPE) - Equipment, such as respirators, gloves, safety glasses and chemical-resistant clothing, worn to protect individuals from contact with known or anticipated chemical hazards.

Predicted Normal Values - Expected values for various lung volumes and flow rates derived from healthy populations.

Protease - A class of enzymes that speeds up the breakdown of the chemical bonds between connecting amino acids in proteins.

Protein - A class of chemical compounds found in plant and animal cells. Proteins are made up of long chains of amino acids.

Pulmonary Function Test (PFT) - Tests, such as spirometry, are used to measure different aspects of lung function. The tests frequently are used to establish normal baselines or to detect and measure lung abnormalities not evident from chest x-rays or not associated with symptoms.

RAST (RadioAllergoSorbent Test) - A laboratory test for detecting and measuring antibodies in the blood of persons exposed to excessive airborne concentrations of specific allergens.

Self-Contained Breathing Apparatus (SCBA) - A specialized air supplying respirator that is connected to a source of compressed air, compressed or liquid oxygen, or oxygen-generating chemicals that is worn by a worker.

Sensitization - A condition in which, or a process by which, the immune system recognizes a substance as foreign to the body. Sensitization is an indication of exposure to an enzyme. When individuals develop antibodies to an enzyme, they are considered to be sensitized to that particular enzyme.

Sensitized - An individual's ability to develop a sensitivity by forming antibodies resulting from antigen exposure.

Sensitizer - A substance with the capacity to produce sensitization.

Skin Prick Test - A technique for detecting antibodies in persons exposed to excessive airborne concentrations of specific allergens. The test consists of pricking the skin with a solution of the enzyme. In a sensitized individual, a raised reddened area with surrounding erythema (wheal and flare) will appear on the skin.

The Soap and Detergent Association (SDA) - A national, non-profit trade association, founded in 1926, representing the manufacturers of cleaning products and their ingredients.

Spirogram Tracing - A graphic recording of the forced expiratory maneuvers, in either volume-time or volume-flow tracings.

Spirometry - One of the most widely used objective tests of pulmonary function. The technique requires the subject to make a full inspiration, to blow out as hard and rapidly as possible into the spirometer, and to continue exhaling until the subject has breathed out as much air as possible. Measurements include the total volume of air exhaled or the forced vital capacity (FVC), the volume of gas exhaled during the first second (FEV_1), and flow rates.

Starch - A chemical compound found in plant and animal cells and made up of long chains of repeating sugar molecules. It serves as an energy source.

Type I Hypersensitivity - A specific form of allergy, also known as immediate hypersensitivity, involving IgE antibodies and mediated by the release of histamine.

Ventilation - A method for controlling a work environment through the use of airflow.

NOTES