Determining Hydrogen Peroxide Exposure of Employees at Company XYZ

By

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A Research Paper

Submitted in Partial Fulfillment of the
Requirements for the
Master of Science Degree
With a Major in

Risk Control

Approved: _3_ Semester Credits

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University of Wisconsin-Stout
December 2002

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ABSTRACT

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Determining Hydrogen Peroxide Exposure of Employees at Company XYZ
(Title)

M.S. in Risk Control	Dr. Brian Finder	December 2002	58
(Graduate Major)	(Research Advisor)	(Month/Year)	(Pages)

American Psychology Association Style Manual
(Name of Style Manual used in this Study)

The significance of this study stems from the plethora of health effects associated with the exposure of industrial hydrogen peroxide concentrations. An extensive literature review established the serious health effects resulting from both acute and chronic hydrogen peroxide exposure. Monitoring was performed using Draeger-Tubes® and a Pac III measuring device. Previous Draeger-Tube® and time weighted average data was also obtained to help make informed conclusions. Results lead the researcher to conclude that employees at Company XYZ are being overexposed to hydrogen peroxide only during the start-up stage when the equipment is being sterilized. Several control options are recommended for consideration, each having benefits as well as concerns. Engineering controls are preferred, but respiratory protection usage is practical under the circumstances. The study found that the threat of hydrogen peroxide overexposure is in fact true at certain operational stages and that such exposure may lead to serious health effects in future.

ACKNOWLEDGEMENT

I would like to thank my family for all their caring and support. I would also like to express my gratitude to Dr. Brian Finder for inspiring the completed work and the risk control staff who were always willing to listen. I extend great appreciation to Steven Senor, for all the help and support you gave me. Finally, I would like to thank the people whom I have developed a network of support with over the time spent in this program. The collaboration and sharing will always be remembered.

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Chapter I

Introduction

According to American Conference of Governmental Industrial Hygienists (ACGIH) (2002), hydrogen peroxide is a confirmed animal carcinogen with unknown relevance to human carcinogenicity. Zienolddiny, Ryberg, & Haugen (2000) found that a 30% concentration of hydrogen peroxide displayed mutagenic effects that may be due to inhibitory action of reactive oxygen species on cellular proteins such as DNA repair enzymes and DNA polymerases (units that replicate DNA). Hydrogen peroxide exposure to a currently infirm person may cause serious health side effects. Arduino (2000), of the Centers of Disease Control and Prevention, noted that three hemodialysis patients (treatment for kidney failure) required blood transfusions when internally exposed to 10-20 ppm of residual hydrogen peroxide after the disinfection of a dialysis water treatment system. Thus, the negative health effects associated with hydrogen peroxide exposure should be taken into account for workers who utilize the chemical in manufacturing processes.

Workers may be exposed to hydrogen peroxide in the form of inhalation, skin/eye contact, and ingestion. According to MedNets (n.d.), solutions of hydrogen peroxide greater then 20% are potentially corrosive and can cause blistering burns when contacting skin. Ingestion can cause extreme irritation, inflammation, and burns of the digestive tract. The Agency for Toxic Substances and Disease Registry (ATSDR) (n.d.) states that there is no proven antidote for hydrogen peroxide poisoning, but its effects can be treated and most people fully recover. Thus, companies need to evaluate hydrogen peroxide utilization and ensure that their employees are being protected from all possible exposures.

Employees at XYZ Company are being exposed to hydrogen peroxide on two new equipment lines that commenced operation in March 2002. Ten to twenty workers are being exposed to hydrogen peroxide in vapor and liquid form from a 35% hydrogen peroxide solution, which is being used to sterilize plastic wrapping complying with Food and Drug Administration (FDA) standards. The wrapping moves through a hydrogen peroxide bath, where the excess is squeegeed off before being filled with product. Workers use a watering can-type container to refill the hydrogen peroxide bath. A door to the squeegee area allows for maintenance. It is likely, determined by worker complaints and previous air monitoring, that employees at XYZ Company are being exposed to hydrogen peroxide concentrations above threshold limit values (TLV) and permissible exposure limits (PEL).

Purpose

The purpose of this study is to evaluate the extent of airborne hydrogen peroxide exposure to XYZ Company employees during wrapper sterilization.

Research Objectives

Goals of the study are:

- To ascertain if workers are being overexposed to hydrogen peroxide.
- To identify chronic and acute exposure issues.

Background and Significance

It has been reasonably documented that hydrogen peroxide poses numerous health hazards to exposed individuals, which could ultimately cost an organization money from a medical and indemnity standpoint. However, worker health would not be the only form of loss the company could sustain as a result of hydrogen peroxide overexposure to its employees. Areas of potential loss leading to incur costs include equipment impairment, facility damage, environmental and public exposure, product contamination, material loss, and legal repercussions.

Hydrogen peroxide is a corrosive chemical that may damage wiring or metals that it contacts (Fischer Scientific, 2001). Not only would there be a fire potential from damaged wiring, but also from the chemical itself. When contacting organic materials, hydrogen peroxide may cause a fire to develop. Thus, hydrogen peroxide poses a threat to equipment integrity. If continued exposures occur, process equipment may begin to deteriorate. Equipment deterioration could ultimately lead to equipment failure, which in turn could cost the company in new equipment, equipment repair, and production downtime. The fire potential not only affects equipment, but also the facility itself.

A fire that would affect production equipment can easily damage more of the facility. According to Fischer Scientific (2001), since hydrogen peroxide reacts with so many chemicals, special considerations must be taken if a fire were to occur. Both carbon dioxide and dry chemical extinguishers are not recommended for use on a hydrogen peroxide chemical fire. Thus, not only can costs occur in the event of a fire, but also it is possible to increase those costs by incorrectly responding to a minor incident. Before an incident like a fire should take place, other facility considerations, such as storage, should be examined. Hydrogen peroxide needs to be kept away from heat, ignition sources, and open flames, as well as separated from combustible materials. Storage spaces best suited for hydrogen peroxide are cool, dry, and well-ventilated areas protected from light (Fischer Scientific, 2001). If a spill should occur, it is recommended that it not be allowed to drain into the sewer system as that could create environmental exposure issues.

Improper disposal of hydrogen peroxide may lead to environmental damage as well as direct public exposure. Since it has been established that hydrogen peroxide exposure poses health hazards to employees, then exposing the chemical to the public may have similar effects. If a large scale spillage event should occur, the company may be liable and will be responsible for remediation effects which would primarily consist of containing the hydrogen peroxide, diluting it, and sending it to an appropriate waste facility. The public could be exposed to hydrogen peroxide either from a spill, or from contaminated product containing residual chemicals from the sterilization process. Costs can accrue from treating public exposure, as well as those related to negative publicity.

Another potential loss is from contaminated product. If process machinery is not working correctly and larger amounts of hydrogen peroxide is left on wrapping, the product may not meet FDA standards. The losses that would result from this kind of occurrence include scrapped wrapping, wasted raw material (product), downtime to adjust equipment, and wasted hydrogen peroxide. Aside from the obvious costs of materials, there is also the consideration of waste handling. Any hydrogen peroxide that cannot be recovered or recycled needs to be handled as hazardous waste and sent to a Resource Conservation and Recovery Act (RCRA) approved waste facility (Fischer Scientific, 2001).

There may also be legal repercussions from acts related to hydrogen peroxide exposure. The FDA may stop production if food standards are not being met. The

Environmental Protection Agency regulates environmental exposures, as well as hazardous waste considerations. Also, civil suits may result from public exposure. Thus, a company must be concerned with all areas for potential loss, not just focusing on the health hazard posed to its employees.

Definition of Terms

There are several terms that need to be defined for clarity of understanding. These definitions include:

- Threshold Limit Values (TLV) - The airborne limits of permitted concentrations of hazardous chemicals represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect, established by ACGIH (SilverPlatter Information, n.d.).
- Permissible Exposure Limits (PEL) – is the maximum amount or concentration of a chemical that a worker may be exposed to under Occupational Safety and Health Administration (OSHA) regulations (MSDS HyperGlossary, 2002).
- Time Weighted Average (TWA) - allows a time-weighted average concentration for a normal 8-hour working day and a 40-hour working week, to which nearly all workers may be repeatedly exposed day after day, without adverse effect (SilverPlatter Information, n.d.).
- Immediately Dangerous to Life & Health (IDLH) - poses an immediate threat to life, would cause, irreversible adverse health effects, or would

impair an individual's ability to escape from a dangerous atmosphere (MSDS HyperGlossary, 2002).

Assumptions & Limitations

The researcher makes the following assumptions and is aware of possible limitations:

- The previously collected measurement data was gathered in a scientifically approved method.
- Appropriate measurement equipment was utilized.
- There is little acute and chronic hydrogen peroxide exposure research available that allows for determining short and long-term effects.
- Due to time and supply constraints regular calibration of monitoring equipment was not performed, which may lead to skewed conclusions.

Chapter II

Literature Review

Introduction

As speculated by the researcher, hydrogen peroxide can be found in most households. Due to the common appearance and use in the household, it is plausible that a chevalier attitude has been adopted when dealing with hydrogen peroxide in an industrial setting. As detailed in Chapter 1, hydrogen peroxide can cause minor to serious health effects. In this chapter, however, industrial uses of hydrogen peroxide, the properties of hydrogen peroxide, airborne concentration measurement methodologies, control measures to minimize or eliminate exposure, treatments of acute and chronic exposure, and possible sterilization alternatives will be examined.

Hydrogen Peroxide Usage

Since it was first commercialized in the 1800s, hydrogen peroxide production has grown to over a billion pounds per year (as 100% concentration). Hydrogen peroxide is available throughout the U.S. in drum, tote, mini-bulk, and bulk quantity concentrations of 35% or 50% by weight (H2O2, n.d.). In industry, hydrogen peroxide is used as a bleaching agent for textiles and paper, as a component of rocket fuels, a reagent for producing foam rubber and organic chemicals (Agency for Toxic Substances and Disease Registry (ATSDR), n.d.), dentistry (Walsh, 2000) and as a method of sterilization in the food, pharmaceutical, and semiconductor industries. The Environmental Protection Agency (EPA) (n.d.) lists other industrial uses for hydrogen peroxide that include substitution for chlorine in water and sewage treatment, metal refining and cleaning, wine distillation, electroplating, antiseptics, and manufacturing of cosmetics.

Hydrogen Peroxide Properties

Hydrogen peroxide is a common chemical found in many households whose use and sanitation properties are well known. Industrial concentrations of hydrogen peroxide may display different properties than the household variety. Hydrogen peroxide is a colorless liquid with a slightly sharp odor and bitter taste (Occupational Safety and Health Administration (OSHA), n.d.) that can be detected only at high concentrations, thus the presence or absence of odors is not an adequate measure of exposure (ATSDR, n.d.). When targeting eyes, skin, and the respiratory system (National Institute of Occupational Safety and Health (NIOSH), 1997, p. 168), elevated airborne concentrations of hydrogen peroxide are known to cause eye, nose, and throat irritation from inhalation, lead to corneal ulcer, erythema (skin redness) when ingested, and bleach hair upon contact. From an inhalation standpoint, the American Conference of Governmental Industrial Hygiene (ACGIH), National Institute of Occupational Safety and Health (NIOSH), and Occupational Safety and Health Administration (OSHA) have established a 1 part-per-million (ppm) time weighted average (TWA) exposure limit concentration and immediately dangerous to life and health (IDLH) concentration of 75 ppm. No short-term exposure limit and ceiling concentration have been established (OSHA, n.d.). Although several governmental agencies have set exposure limits, it seems possible that the established allowable concentrations may still pose a health hazard.

Hydrogen peroxide poses a health hazard to people through three types of direct exposure; inhalation, skin/eye contact, and ingestion. The hydrogen peroxide ATSDR website states that inhalation of vapors, mists, or aerosols from concentrated solutions of hydrogen peroxide can "cause significant morbidity". This statement is accurate when using it in the context of increased sickness/injury, though it is likely to be inappropriate when mortality is in question. Even though hydrogen peroxide is poorly absorbed through undamaged skin, a concentration of 10%, hydrogen peroxide (found in some hair-bleaching solutions) can be strongly irritating and corrosive. If ingested, solutions of hydrogen peroxide with concentrations of less than 9% are generally nontoxic, however, industrial-strength solutions greater than 10% cause systemic toxicity and has been associated with fatalities (ATSDR, n.d.). Thus, when handling industrial-strength hydrogen peroxide concentrations, precautions should be taken to minimize exposure.

Not only does hydrogen peroxide possess significant toxicological effects, but it also has a high fire or explosion hazard potential. Contact between hydrogen peroxide and combustible materials, such as cotton, wood, paper, or oil, may result in spontaneous combustion. Organic materials such as alcohols, ketones, glycerol can cause violent explosions when mixed with hydrogen peroxide. Violent explosions may also result from metals contacting hydrogen peroxide when metal oxides are created. Chemical instability resulting from exposure to radiant heat, sources of ignition, and physical or mechanical disturbances may also cause a fire or explosion (OSHA, n.d.). OSHA recommends water extinguishment for small fires, carbon dioxide and dry chemical extinguishment being highly unfavorable. Large fires should be flooded with water from an adequate distance (OSHA, n.d.). Thus, the fire potential posed by hydrogen peroxide should be considered when the chemical is stored on-site from not only a safety perspective but also in regards to regulatory compliance.

Regulatory compliance is another area that concerns hydrogen peroxide use. To be in compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), employers need to notify the National Response Center (NRC) immediately if an amount equal to or greater than 1 lb. is released within a 24-hour period that exposes people outside the facility (OSHA, n.d.). Hydrogen peroxide may also pose an environmental hazard if discharged in large quantities. Thus, it is not only human health hazards that are of concern, but environmental stability as well.

Airborne Concentrations Measurement Methodologies

There are several different apparatus types that measure hydrogen peroxide. Other apparatuses merely detect the presence of hydrogen peroxide and/or measure the contaminant concentrations in the area, while other apparatus types measure time weighted averages as well as take instantaneous concentration readings. Each available apparatus has corresponding advantages and disadvantages concerning the measurement of hydrogen peroxide concentrations.

- Draeger Tubes® (indicator) – Indicator tubes are simple to use, quick and reasonably accurate devices that are capable of measuring 0.1-3 ppm concentrations (Draeger, Inc., 2002). Indicator tubes are made of glass, and fragments that occur in food processing facilities may result in legal actions if glass should be found in the product. Indicator tubes are useful for area concentration monitoring, but limited in determining time-weighted averages (TWA) of employees. To use the indicator tube, the ends must be broken and the tube placed in a hand pump. Figure 1 shows an indicator tube in a hand pump.

Air is sucked through the tube a number of times (as per instructions), to gauge the concentration of the gas being measured.

Figure 1

- Color Diffusion Tubes – Color diffusion tubes give on the spot results while being easy to use, disposable, and displays hydrogen peroxide concentrations in the form of a color change. Figure 2 represents the variety of color diffusion tubes available for various chemicals. According to the SKC online catalog (2002), color diffusion tubes are an accurate and reliable TWA sampling method with a calibrated scale printed directly on the tube that allows for on-the-spot reading of the exposure with no charts or lengthy calculations needed. The range of concentration detection may vary depending on the product, but commonly detects 0.1-3 ppm if a scale is incorporated on the tube (Draeger, Inc., 2002). Some tubes do not determine exact concentrations and the scale may not be appropriate for the concentration levels present. Unlike indicator tubes, color diffusion tubes tend to provide some TWA information. If the tube is left in a single area to determine

Figure 2

TWA, the results will provide skewed data. If, like at Company XYZ, employees are in and out of the contaminated area, a true TWA will not be reached. To use a color diffusion tube, an end is broken and exposed to the atmosphere, thus no air pumping is required (SKC, 2002).

Figure 2

- Single gas (hydrogen peroxide) monitor – Single gas monitors have a detection range of 0-20.0 ppm hydrogen peroxide (Draeger, Inc., 2002), which may provide better readings than indicator or color diffusion tubes that measure concentrations of 0-3.0 ppm. Through the researcher's experience, this equipment is easy to use/user friendly, tends to be more precise when correctly calibrated, and may be cost effective for long-term measuring. The disadvantages of the equipment include that it is limited to single gas, may become obsolete, and the results may be inaccurate if calibration was not performed or performed incorrectly. Training is also required to use gas monitors correctly. It has been the researcher's experience to see this device being used for area measurements alone, although it can be used for TWA measurements of hydrogen peroxide concentrations. Figure

3 gives a good representation of what a single gas monitor would look like. Turning on the device is the extent needed to take measurements.

Figure 3

- Impingement tubes with air sampling pump – Air sampling impingent tubes is a method of determining 8-hour TWAs with accurate results. However, they are bulky and awkward to wear, also made of glass that could prove detrimental in the food industry, and possible apparatus tampering may lead to inaccurate results. The device is attached to an air pump to draw in air through the impingement tube, which is secured to an employee's clothing. Once the sampling is complete, the impingement tube is sent to a laboratory to determine the airborne gas concentration.
- Monitoring Badges – Monitoring badges (see Figure 4) are easy to use and may provide TWA-based results. The badges must be sent in to a laboratory that analyzes the badges for the specified chemical. Costs may be a prohibitive factor when exploring this measuring method. According to a sales representative of Environmental Monitoring Technology, one badge kit (includes lab results) costs $40.00. Also, there is a concern with employee tampering of the badge, resulting

in inaccurate data collection. To use, the badge is placed on an employee's clothing and is not removed until that employee is finished working.

Figure 4

- For the monitoring of hydrogen peroxide, OSHA recommends a partially validated method, using a midget fritted glass bubbler (MFGB) containing 15 mL TiOSO4, to determine worker exposure to airborne hydrogen peroxide. Samples would be collected at the prescribed rate of 0.5 liter/minute until a collection volume of 100 liters is reached. Colorimetric methods are used to analyze the sample (OSHA, n.d.)

Control Measures

Engineering and administrative controls should be examined first when trying to minimize workplace exposure of hazardous materials. Engineering controls focus on redesigning or revising a process in order to reduce or eliminate hazardous exposure (Asfahl, 1999, p52). According to Goetsch (1996, p467), engineering controls include strategies such as replacing a hazardous chemical with a less harmful one, or redesigning a process to reduce hazardous material exposure, or isolating a process to minimize the number of workers exposed. Administrative controls focus on personnel solutions, for example worker rotation, longer/more frequent breaks, and other schedule-oriented strategies (Goetsch, 1996). If engineering and administrative controls are not feasible, personal protective equipment (PPE) may be used. Based on the researcher's observations, engineering and administrative (work practices) controls that may improve air quality and lessen hydrogen peroxide exposure presumably includes (but may not be limited to) process enclosure, local exhaust ventilation, dilution ventilation, and housekeeping activities.

Based on use in the food packaging industry, as observed by the researcher, it appears that viable control measures for airborne contaminants include the use of process enclosures, local exhaust and dilution ventilation, as well as good housekeeping practices. Process enclosures surround the source of possible exposure (Goetsch, 1996, p463), potentially sealing the machinery so that in theory, hydrogen peroxide or similar-type chemical hazards cannot escape. Ventilation may provide more air to dilute the present chemical concentrations or removed the air contaminant from the workstation. Dilution ventilation aerates (with outside air) contaminated air to control possible airborne health hazards, fire and explosive conditions, odors, and nuisance type contamination. Local exhaust ventilation is designed to capture and remove airborne contaminants before they can escape into the workplace atmosphere (Committee on Industrial Ventilation (CIV), 1988). Both local exhaust and dilution-based forms of ventilation may become more effective placed in different areas on a production line. Dilution ventilation may prove more efficient if directed at areas of high contaminant concentrations, although this type of system is not as satisfactory for health hazard control as local exhaust (CIV, 1988). Local exhaust ventilation would provide the best results if placed directly over/around the source of airborne contamination. If the exhaust inlets are fixed and unable to be resituated due to previously established ventilation, then the layout of the entire product line should be examined in order to best exploit the current system. Good housekeeping (i.e. workplace cleanliness, waste disposal, and adequate washing) is another practice that may minimize employee exposure by eliminating residual hydrogen peroxide from contaminated surface areas (Goetsch, 1996, p466).

It is recognized that in some instances, engineering and administrative controls may not always provide enough protection against certain chemicals. In such cases, personal protective equipment may be utilized. Personal protective equipment should be evaluated for its use with hydrogen peroxide since the chemical has stringent requirements (NIOSH, 1997). Performance data and manufacturers' recommendations are possible sources of information that can lead to informed decisions about personal protective equipment selection. The selection of appropriate personal protective equipment should be based on the worker's potential exposure to hydrogen peroxide via all routs of entry (OSHA, n.d.). Items of personal protective equipment that may be utilized include safety glasses, respirators, protective clothing, and gloves. The following provides more detail of the personal protective equipment possibly used when handling hydrogen peroxide:

Comment: Get respirator information from NIOSH book

Safety glasses – splash-proof chemical safety glasses/goggles or face shields should be worn during any operation in which a solvent, caustic, or other toxic substance may be splashed into the eyes of the worker(s) (OSHA, n.d.).

Respirator – NIOSH recommends supplied-air respirators or a self-contained breathing apparatus when in environments containing greater than 10 ppm concentrations of hydrogen peroxide. Thus, cartridge type respirators would not provide necessary protection is such an environment and should not be used (NIOSH, 1997).

Protective clothing – Protective clothing may or may not be needed, depending on the level/type of hydrogen peroxide exposure (either actual or potential). As with regular apparel, if hydrogen peroxide should be spilled on the protective clothing it should be removed immediately and washed (if not disposed of) before wearing again (Izu, Yamamoto, & Asahi, 2000).

Gloves – Table 1 illustrates the protection certain types of gloves provide in the event of hydrogen peroxide exposure. Given an analysis of this data, it is obvious that polyvinyl alcohol gloves should be avoided when working with hydrogen peroxide. The other glove choices may be used once the actual hydrogen peroxide exposure has been determined. If employees are working with the chemical for less that 4 hours, then the polyvinyl chloride or 4H (PE/EVAL) gloves will provide adequate protection and using gloves that are effective for greater than 8 hours are not necessary.

Table 1: *Resistance of Various Materials to Permeation by Hydrogen Peroxide (30-70%)*

Material	Breakthrough Time (hr)
Butyl Rubber	>8
Natural Rubber	>8
Nitrile Rubber	>8
Viton	>8
Responder	>8
Polyvinyl Chloride	>4
4H (PE/EVAL)	>4

Neoprene	Caution 1 to 4
Polyvinyl Alcohol	<1(Not recommended)

Table compiled from information found in OSHA, n.d.

Exposure Treatment Methodologies

According to ATSDR (n.d.), there is no proven antidote for hydrogen peroxide poisoning, but its effects can be treated and most people achieve a full recovery. People who exhibit serious overexposure-related symptoms may need close medical attention for up to 72 hours. After a single small exposure with quick recovery, delayed or long-term effects are unlikely to occur. After a severe exposure, symptoms may be delayed up to 72 hours. The Fischer Scientific (2001) hydrogen peroxide MSDS breaks treatment up by exposure route. For skin contact, it is recommended to get immediate medical aid as well as flushing the skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing. Induced vomiting is not recommended if hydrogen peroxide is ingested. While the victim is conscious, 2-4 cups of milk or water should be administered to dilute the chemical, while seeking medical attention. A victim should be moved to fresh air immediately after inhaling hydrogen peroxide, while seeking medical aid. When the victim has difficulty breathing, oxygen should be administered. Mouth-to-mouth respiration should never be attempted due to the chance of hydrogen peroxide exposure through medical aid. When breathing ceases, artificial respiration using oxygen and a suitable mechanical device such as a bag and a mask should be applied (ATSDR, n.d).

There are medical procedures that apply to severe acute hydrogen peroxide exposure, but there is little in the way of determining chronic exposure effects. There are no specific blood and urine tests that can indicate exposure to hydrogen peroxide.

However, blood tests and a chest X-ray may be used to evaluate lung injury. Generally, the severity of irritation symptoms is the best measure of the seriousness of the exposure (Fischer Scientific, 2001). Thus, chronic exposure health effects may lead to further health deterioration due to inadequate medical attention.

Sterilization Alternatives

Hydrogen peroxide is the most common sterilant for materials in aseptic packaging systems because of its impact on sporicidal activity. In a 35-percent solution, hydrogen peroxide completely destroys spores in a matter of seconds (Bakka, 1997). There is a difference between sterilization and sanitation. Sterilization is a treatment that frees the treated object of all living organisms (Hill, n.d.). Sanitization is the use of any effect method or substance to a clean surface for the reduction of the bacterial count, to a safe and acceptable level (Melrose Chemicals Ltd., n.d.) The purpose of this section is to explore different sterilization/disinfection and sanitization techniques.

Vaporized Hydrogen Peroxide

Interest in hydrogen peroxide vapour as a sterilant is increasing due to potential employee exposure health risks and environmental concerns posed by conventional chemical sterilants (Lorence, 1999). According to McDonnell (2002), atmospheric vaporized hydrogen peroxide (VHP) provides rapid and low-temperature decontamination of areas that may be contaminated with micro-organisms. Lorence (1999) states that VHPs are highly sporicidal (kills micro-organisms) at very low concentrations. Vacuum VHP systems provide greater penetration for sealed areas, including packaged equipment. Concerning environmental safety, VHPs have the better profile. VHPs quickly break down in the environment into oxygen and water vapor, thus producing little to no environmental concerns. Exposure concentrations remain the same as liquid hydrogen peroxide, being 1ppm for an 8-hour time weighted average, and short-term danger level of 75 ppm for 30 minutes (McDonnell, 2002). Thus, vaporized hydrogen peroxide proves a sterilization alternative that may be utilized in the food industry as well as clean room use.

Chlorine Use

Chlorine is used to sanitize produce, but is limited in its effectiveness. Chlorine does not suppress listeria growth in shredded lettuce or salmonella in tomatoes, which may indicate ineffectiveness in treating packaging as well. Chlorine may react with some food constituents, potentially forming toxic by-products. The possible hazards associated with chlorine has stimulated search for safer and yet more effective substitutes. Among those being looked at are ozone and trisodium phosphate (Hunter, 1999). According to the Canadian Centre for Occupational Health and Safety (CCOHS, 2002), chlorine concentrations of 1 to 2 ppm produce significant irritation and coughing, difficulty breathing, and headache. Concentrations of 1 to 4 ppm are considered unbearable. Severe respiratory tract damage including bronchitis and pulmonary edema (a potentially fatal accumulation of fluid in the lungs) has been observed after even relatively low, brief exposures (estimates range from 15 to 60 ppm). Direct contact with chlorine in liquid form can cause frostbite. Blistering, tissue death and gangrene may also develop in severe cases of direct chlorine contact (CCOHS, 2002). Thus, due to potential serious health effect, chlorine sterilization may not be the best alternative to hydrogen peroxide use.

Natural Methods of Sterilization

According to Hunter (1999), a naturally occurring compound termed methyl jasmonate is capable of doubling the shelf life of certain produce. Chemically, methyl jasmonate is produced when a plant's natural defense mechanism is activated. Methyl jasmonate triggers compound production that makes plants more resistant to bacterial and fungal attacks. The vapor has decreased bacterial growth a thousand fold for up to two weeks on fresh-cut celery (Hunter, 1999). It is probable that if methyl jasmonte is an effective treatment for produce, then such a natural chemical may be effective when treating packaging material and consequently the use if this substitute should be further explored.

UV Light Technology

Ultraviolet light treatment is another sterilization alternative that may potentially eliminate the need for hydrogen peroxide. Hanovia Ltd has developed a surface disinfection (sterilization) system using Ultraviolet (UV) treatment that destroys all micro-organisms without the expense of heat or chemicals. Packaging can be exposed for less than one minute to provide complete disinfection and can be installed on existing packaging lines (Hanovia Ltd., 1996). The rapid disinfection and utilization of current packaging line makes UV light a viable alternative to the use of hydrogen peroxide. Thus, there are several options for sterilization alternatives that can be explored to minimize or eliminate hydrogen peroxide exposure.

Summary

Several factors should be examined to minimize or eliminate the potential airborne contaminant exposure to industrial workers. If alternative sterilization techniques are infeasible, a company needs to be well aware of the inherent dangers associated with the use of hydrogen peroxide as well as the possible control measures available to minimize employee exposure. Several control measures that are available include process enclosure, dilution and local exhaust ventilation, and housekeeping. Even though, control measures may be in place, exposure verification may be needed, especially since there is no known treatment for hydrogen peroxide poisoning. Based on a measurement analysis, it appears that single gas monitors as well as indicator tubes will provide greater flexibility in obtaining hydrogen peroxide samples without hindering the normal work process.

Chapter III

Methodology

Introduction

Occupational exposure to chemicals is a widespread issue dealing with adversity to the health and safety of employees and of grave concern to Risk Control professionals. The potential employee exposures to hydrogen peroxide are quantified using industrial hygiene sampling methods. As stated in Chapter II, sampling can be performed utilizing indicator tubes (Draeger-Tubes®) and a single gas monitor (Pac III). This chapter will provide a description of current practices, detail the general sampling area, describe the instruments used to collect the data, data collection methodology, and conclude with the research limitations pertaining to the methodology.

Current Practices

Company XYZ is currently operating two prototype food production lines for three shifts that utilize hydrogen peroxide in 35 % concentration for wrapper sterilization. Three phases of operation, start-up (sterilization), normal run-time, and shut down, expose employees to varying amounts of airborne hydrogen peroxide. Inhalation exposure is the primary concern, although there are contact exposure issues with handling small open containers of the chemical. The company is currently practicing several engineering and administrative control measures in order to minimize employee exposure to airborne hydrogen peroxide.

Engineering controls currently being practiced include leak minimization, semi-process enclosure, and ventilation. When process vapor leaks were identified at machinery doors, engineers installed bolts to provide a better seal. This strategy has had limited effects. Other areas of identified leaks have been treated with duct tape or left alone due to process function. The bath area as well as the hydrogen peroxide residue removal is enclosed. Both dilution and local exhaust ventilation are currently being utilized in the process. The machine layout may prohibit effective ventilation of the area with the current local exhaust system. A future development is the automation of hydrogen peroxide injection in order to eliminate employee handling of the chemical in liquid form.

Not only are engineering controls being utilized in the process area, but administrative controls are helping to minimize hydrogen peroxide exposure as well. Employees routinely clean and maintain the area by washing and wiping down the equipment and flooring, with the intent of minimizing residual hydrogen peroxide exposure through direct contact with the skin. Another administrative control was the moving of workstations further away from identified leak points. If it is determined that the above-mentioned control measures do not provide adequate protection, supplied air respirators may have to be utilized. Even though it is likely that workers are being exposed to airborne hydrogen peroxide, the control measures currently being utilized display a concern for the employees' well being.

Written procedures and standards (see Appendix B) supplement the control measures currently being practiced. One example of such standards is that the levels of hydrogen peroxide concentration required for employee evacuation have been established. However, due to production quotas, it is possible that strict adherence to the procedure may not always be followed, potentially exposing employees to hydrogen peroxide concentrations above the PEL.

General Selection

The immediate area surrounding the two new food production lines at Company XYZ were tested for the presence of airborne hydrogen peroxide. Employee complaints have triggered an awareness of potential overexposure issues. Ten to fifteen employees work the two production lines each shift. The production process involves quality checks, housekeeping activities, and maintenance of normal operation. Prior air monitoring has been completed several times per shift to determine hydrogen peroxide concentration levels and thus establish the need for an area evacuation as necessary (see Appendix A).

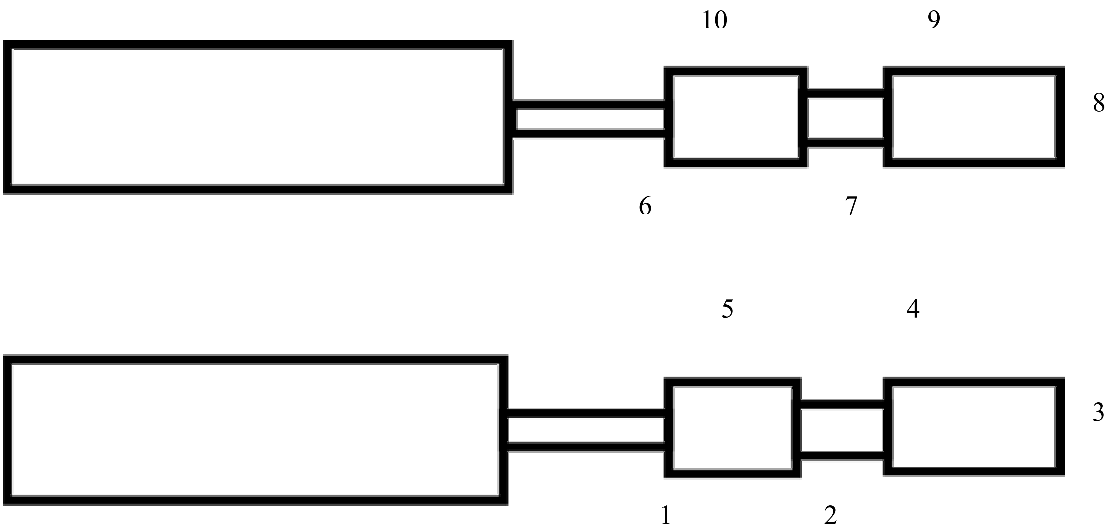
Instrumentation

Two industrial hygiene sampling techniques were utilized to measure hydrogen peroxide concentrations. The gathering of information was completed using a single-gas monitor (Pac III) and Draeger-Tube® indicator tubes. The Pac III was a new instrument that had not yet been calibrated by the researcher. The manufacturer device manual recommended that the unit be calibrated on a regular basis. Due to the vague recommendations of the manufacturer a cross referencing strategy (detailed in Data Collection), between the Draeger-Tubes® and Pac III monitor, was utilized to help validate the Pac III information. The Draeger-Tubes® did not have to be calibrated, though the number of hand pump squeezes performed followed manufacturer instructions. Before measuring, a leak test was performed on the hand pump. This test involves placing an unbroken tube in the pump and squeezing the pump. If the pump holds the squeeze depression, then there are no leaks present. The tubes were utilized before their expiration date of 1/04. Performing area monitoring versus personal monitoring was chosen due to readily available equipment and cost considerations, since personal monitors are expensive.

Data Collection

The use of supplied air respiratory protection may be necessary at elevated concentrations, though at the expected low concentrations may not be needed to protect the researcher while monitoring hydrogen peroxide at Company XYZ. Three types of data were collected for this study; ambient concentrations, real-time data, and TWA-based data from an outside consultant. Direct contact with the employees was avoided for this study. Ambient concentrations were gathered using Draeger-Tube® indicator tubes. One set of sampling data was measured by walking around the two production lines while drawing air through the indicator tube. The value was then recorded on a legal pad. Real-time concentration data (which is also ambient measurements) was gathered using a Pac III single gas monitor. The monitor was carried around the production lines and the concentrations were recorded on paper. A larger amount of data was gathered from the Pac III, since readings did not take as long as Draeger-Tube® ambient measurements. A second set of sampling data was performed with side-by-side monitoring, using the Pac III and indicator tubes, to serve as a cross-referencing function in order to verify the results received. This was performed by checking the Pac III periodically during the course of the 20 consecutive air draws required for the Draeger-Tubes®. The areas of measurement were chosen based on employee operation around the equipment containing hydrogen peroxide. Figure 5 represents the two food production lines and illustrates where measurements were taken. Locations 1 and 6 are the closest stations to the hydrogen bath area. Locations 2 and 7 are situated where the identified vapor leaks are present.

Figure 5



All previously collected data is recorded in spreadsheet form as illustrated in Appendix A. Data concerning TWA concentrations, prepared by an outside consultant, was made available to enhance the study's findings. Thus, through these three types of data, it may be possible to determine if employees at Company XYZ are being overexposed to airborne hydrogen peroxide.

Limitations

Since this study focused on air concentrations, minimal limitations due to human interaction occurred. A potential human error limitation would involve faulty data collection or instrument use, though the researcher believes that the probability of such an occurrence is negligible. Another area of potential limitation includes instrumentation sensitivity and instrument appropriateness. The instruments used provided helpful data, though other instruments may have supplied more accurate or sensitive results. Lastly, the data from the consultant's previous monitoring may or may not be completely accurate.

Chapter IV

Results

Introduction

This study was prompted by the fact that employees were complaining about working conditions in an environment that may cause serious health effects. Monitoring was performed to ascertain whether employees are being exposed to elevated concentrations of hydrogen peroxide, thus being in noncompliance with OSHA regulations. This chapter will present the data gathered from monitoring efforts subsequent to reviewing the research objectives and research methodology. A discussion pertaining to the monitoring results follows the presented data.

Research Objectives

The objectives of this research paper involved determining whether employees at Company XYZ are being overexposed to airborne hydrogen peroxide as well as researching the potential health effects resulting from hydrogen peroxide exposure. In order to determine if employees were being overexposed, hydrogen peroxide monitoring was performed using several apparatuses in addition to previous monitoring data. The apparatuses utilized will be delineated later in the chapter. A literature review, detailed in Chapter II, was executed to ascertain the potential health effects of hydrogen peroxide overexposure.

Data Collection – Objective 1

Monitoring was performed using Draeger-Tubes® as well as a Pac III single-gas monitor. A cross-referencing technique was utilized in order to compare the results from the two devices. Previously measured concentration values can be found in Appendix A.

Time-weighted average data was obtained from a consultant's prior monitoring to serve as an 8-hour exposure reference. All three types of the data collection processes were analyzed to determine the extent of employee hydrogen peroxide exposure.

Table 2 – Data Set #1: Measurements taken at random locations surrounding the production lines while both were in start-up stages.

Measurement Locations	Pac III Results
Hydrogen peroxide refilling portal	3.1 ppm
Door area	2.7 ppm
Floor – near vapor check hose	2.6 ppm
End of line	1.9 ppm
1st workstation	1.9 ppm
Between two lines	2.2 ppm
Average	2.28 ppm

Corresponding Draeger-Tube® measurements = 3.0 ppm, 2.5 ppm, 2.0 ppm

Table 3 - Data Set #2: Measurements taken at specified locations (see Figure 5) while both lines were in normal run stages.

Location	Pac III Measurements
1	0.6 ppm
2	0.5 ppm
3	0.8 ppm
4	0.7 ppm
5	0.5 ppm
6	0.5 ppm
7	0.5 ppm

8	0.9 ppm
9	0.7 ppm
10	0.6 ppm
Average	0.63 ppm

Corresponding Draeger-Tube® measurement = 0.5 ppm

Table 4 - Time Weighted Average Data – Consultant prepared

	Morning Sample	**Afternoon Sample**	**8 hour TWA**
Employee 1	2.37 ppm	1.38 ppm	2.00 ppm
Employee 2	1.71 ppm	1.31 ppm	1.56 ppm
Employee 3*		1.36 ppm	

* Morning sample was lost, thus a TWA could not be calculated

Data Collection – Objective 2

Health effects of hydrogen peroxide exposure may result from vapor inhalation, liquid ingestion, as well as direct skin contact. When targeting eyes, skin, and the respiratory system (National Institute of Occupational Safety and Health (NIOSH), 1997, p. 168), elevated airborne concentrations of hydrogen peroxide are known to cause eye, nose, and throat irritation from inhalation, can cause extreme irritation, inflammation, burns of the digestive tract, corneal ulcer, and erythema (skin redness) when ingested. According to MedNets (n.d.), solutions of hydrogen peroxide greater then 20% are potentially corrosive and can cause blistering burns when contacting skin. The previously mentioned health effects all occur from acute exposures. It is the chronic exposure health effects that are harder to identify.

Chronic exposure health effects attributed to hydrogen peroxide are few, although, Zienolddiny, Ryberg, & Haugen (2000) found that a 30% concentration of hydrogen peroxide displayed mutagenic effects after repeated exposure. Also, chronic exposure may cause continual irritation of the respiratory tract and partial or complete lung collapse (ATSRD, n.d.). Thus, even though chronic exposure health effects are not as widely known as acute conditions, there is information that supports the serious nature of being exposed to hydrogen peroxide on a regular basis.

Discussion

The results presented in Table 2 & 3 show that employees are being overexposed to a hydrogen peroxide concentration of 1ppm (OSHA's PEL) at certain operational stages, namely the start-up stage. This was determined by performing hydrogen peroxide monitoring around two food production lines at Company XYZ. The highest concentration of overexposure while both lines were in start-up stage was 3.1 ppm for the Pac III monitor and 3.0 ppm for the Draeger-Tube® measurement. The highest concentration of airborne hydrogen peroxide while both lines were in the normal run stage was 0.9 ppm (Pac III monitor) with a corresponding 0.5 ppm Draeger-Tube® measurement. TWA data, gathered during the start-up stage, indicated employee overexpose. This supports the data collected when both lines were in the start-up stage (Table 2), gathered from the Pac III and Draeger-Tubes® monitoring. The OSHA PEL for hydrogen peroxide is established at 1 ppm, thus it is possible that employees are being overexposed periodically throughout their employment. This overexposure may result in serious health effects.

Chronic and acute hydrogen peroxide exposure should be of employer concern. The research of available literature concerning health effects illustrates the seriousness of possible medical issues. Further result analysis will be discussed in chapter five along with recommendations concerning this industrial hygiene issue.

Chapter V

Discussion/Conclusion & Recommendations

Introduction

The purpose of this study was to evaluate airborne hydrogen peroxide exposure to XYZ Company employees. The objectives were to determine whether or not employees at Company XYZ were being overexposed to airborne hydrogen peroxide as well as investigate the health effects resulting from acute and chronic hydrogen peroxide exposure. In order to determine if employees were being overexposed, hydrogen peroxide monitoring was performed using Draeger devices as well as previous monitoring data. A literature review was conducted to discover the potential health effects of hydrogen peroxide overexposure.

Typically, when there is a design flaw or equipment malfunction, a solution may already exist from a previous incident. Such is not the case at Company XYZ. The production line equipment is a manufacturer prototype, thus it cannot be physically found anywhere else. The issues that arise from the equipment and the chemical it was designed to handle are all unique with no precedence to reference. This chapter will continue the discussion of the results found as well as presenting conclusions based on the data. Recommendations will conclude the study in the form of providing hydrogen peroxide exposure management options.

Discussion/Conclusion

As presented in the results found in Chapter IV and Appendix A, overexposure is likely to occur during the start-up stage of operation. TWA values indicate that tested employees were exposed to elevated hydrogen peroxide concentrations over an 8-hour period. This data was obtained while both lines were in the start-up stage. If the previous monitoring data as found in Appendix A is examined, concentrations over 1 ppm typically occurred when one or both lines were in some phase of sterilization. Thus, the use of engineering and administrative controls could be focused at that specific time and provide sufficient protection from airborne hydrogen peroxide. Also observed on the monitoring documentation of Appendix A, production lines where overexposure had occurred were shut down due to the presence of excessive airborne hydrogen peroxide concentrations. This practice was applauded by the researcher and should be strictly followed until control measures are utilized that reduce/eliminate exposure to hydrogen peroxide.

As noted in Chapter IV, health effects related to hydrogen peroxide exposure may result in serious implications to both the employees and Company XYZ. Potential employee implications include increased chance of illness and days away from work, which may result in future health problems and decreased income. Employees working the production lines in question have made complaints about respiratory irritation as well as bleached hair. Thus, there may be significant health implications that have already occurred. Possible company implications resulting from hydrogen peroxide exposure include employees with serious health problems which lead to an increase in employee absences, decrease in morale due to employee knowledge of the working environment, and increased number of sick days as well as turnover rate that may cost Company XYZ financially.

Recommendations

There are several control options that may reduce or eliminate employee exposure to hazardous concentrations of hydrogen peroxide. Weighing the benefits of each option will be necessary to develop a treatment methodology that accommodates the needs of the employees as well as the company. The following treatment options are not an all-inclusive list, merely the researcher's opinion as to the best management of hydrogen peroxide exposure.

As mentioned in Chapter II, a supplied air respirator is the only form of PPE that is effective in hydrogen peroxide contaminated air. Since it is likely that overexposure is only occurring during the start-up stage, this is the only time supplied air respirators are needed. Not only is the time limited to start-up, but also the number of employees that need to be present during this operation stage. Approximately four employees per shift, instead of ten to twelve that are normally working during production times, need to be present while the equipment is in the start-up stage. Considering the limited number of employees needed on the production line during the start-up stage, supplied air respirator costs will approximately be two thousand dollars, depending on the distributor. Specific operating procedures should be developed, particularly for production lines in the start-up stage in order to ensure that employees are not being overexposed to hydrogen peroxide. Training as well as fit-testing will also need to be undertaken to provide effective management of hydrogen peroxide exposure. The respiratory protection option should be utilized only if engineering controls are not feasible, either from a cost perspective or due to the physical limitations of the plant.

It is possible that various management options related to engineering controls may prove effective in reducing/eliminating exposure to airborne hydrogen peroxide. One engineering control option would be to enclose the area surrounding the hydrogen peroxide vapor leaks. This method would most likely contain airborne hydrogen peroxide vapors so that all employees working on the line are not exposed. Ventilation can be connected to the system to draw hydrogen peroxide vapor out of the area. Even though this method would minimize employee exposure overall, there are still the 4 workers per shift that need to be present while the equipment is in the start-up stage. Depending on its design, the enclosure may concentrate the hydrogen peroxide, which could present a greater hazard than leaving the equipment space open. With the area enclosed, it could be considered a confined space that requires the use of supplied air respirators or even a self-contained breathing apparatus for entry purposes. Thus, confined space training as well as the requirements associated with utilizing respiratory protection would be necessary for this option. Ventilation changes could be a part of an area enclosure control measure, but may also provide an effective treatment on its own.

Changes in the current ventilation system may provide the necessary employee protection by maintaining the airborne hydrogen peroxide concentration below 1 ppm. There are several ventilation change approaches that can be taken; for example additional ventilation can be utilized to remove an increased amount of contaminated air. Exhaust ventilation ducting can be relocated nearer to the floor, where hydrogen peroxide vapors tend to settle toward the floor. Keeping the exhaust ventilation ducting near the ceiling would not be preferred since the airborne hydrogen peroxide would be drawn the through the employees' breathing zone. Floor fans have the same effect of drawing air through employees' breathing zone and should not be used until an effective treatment method has been utilized. Another alternative is to move the production lines so that they are parallel, rather than perpendicular, to the existing ventilation system. This may increase the amount of hydrogen peroxide contaminated air drawn through the ventilation system. Aside from the costs of moving the equipment line, retrofitting the current ventilation system, or creating addition ventilation, monitoring will still need to be performed in order to ascertain whether or not concentrations are above the 1 ppm exposure limit. If ventilation changes are utilized and they do not provide adequate protection, another treatment option may need to be employed.

The only options that will not require regular hydrogen peroxide monitoring are those that do not utilize the chemical. An alternative sterilization method that does not use hydrogen peroxide is an option that could minimize any health or regulatory non-compliance concerns. Based on the literature review, ultraviolet (UV) light sterilization may be an effective alternative that meets Company XYZ's requirements. There are few companies that manufacture UV light sterilization equipment, but those that do, such as Hanovia, will create a system designed for a specific product line. Thus, due to specific company needs, each piece of machinery will have a different cost due to differences in process needs. Another factor that should be explored before this sterilization alternative is chosen would be health concerns related to UV light exposure. This may or may not be a factor considering that with the use of UV light sterilization, direct employee interaction may not be necessary.

There are several areas of further study that may allow the continued use of hydrogen peroxide without additional controls in place. One area of study would be determining if lower hydrogen peroxide concentrations used in the sterilization process are effective in killing microorganisms. Lower hydrogen peroxide solution concentrations may result in the decreased seriousness of health effects related to the airborne exposure of industrial strength solutions. Another area of study includes determining if lower hydrogen peroxide temperatures will be as effective as the elevated temperature currently being used. Hydrogen peroxide at lower temperatures may result in decreasing the amount of airborne hydrogen peroxide employees are being exposed to by reducing its volatility. Thus, with further experimentation, it may be possible that hydrogen peroxide can still be used without exposing employees to harmful concentrations of this chemical.

REFERENCES

The Agency for Toxic Substances and Disease Registry (ATSRD). (n.d.). *Hydrogen peroxide, general information*. Retrieved October 4, 2002 from: www.atsdr.cdc.gov

American Conference of Governmental Industrial Hygienists. (2002). *2002 TLVs and BEIs: threshold limit values for chemical substances and physical agents & biological indices.* Cincinnati, OH: ACGIH.

Arduino, M. (March-April 2000). CDC investigations of noninfectious outbreaks of adverse events in hemodialysis facilities, 1979-1999. *Seminars in dialysis, 13*(2), 86-91.

Asfahl, Ray. (1999). *Industrial safety and health management*. Upper Saddle River, New Jersey: Prentice Hall. p52.

Bakka, Dick. (September 1997). Container sterilizing is key to asceptic beverage quality. *Beverage World*, *116*, p161.

Canadian Centre for Occupational Health and Safety. (2002). *OSH answers: health effects of chlorine.* Retrieved on November 13, 2002 from: www.ccohs.ca/oshanswers/chemicals/chem_profiles/chlorine/health_chlorine.html

Committee on Industrial Ventilation. (1988). *Industrial Ventilation*. American Conference of Governmental Industrial Hygienists: Cincinnati, Ohio. Pp 2.1, 3.1.

Draeger, Inc. (2002). *Draeger tubes*. Retrieved on November 5, 2002 from: www.draeger.com/us/ST/productsnservices/Detection/Mobile_messtechnik/draegerTubes/dt1.jsp

Environmental Protection Agency (EPA). (n.d.) *Emergency first aid treatment guide for hydrogen peroxide*. Retrieved October 4, 2002 from: www.epa.gov/swercepp/ehs/firstaid/7722841.txt

Fischer Scientific. (2/21/2001). *Material safety data sheet: hydrogen peroxide*. Retrieved October 4, 2002 from: file:///FischerScientific/Doug/MSDS/Hydrogen_Peroxide.htm

Goetsch, David. (1996). *Occupational safety and health in the age of high technology*. Columbus, Ohio: Prentice Hall. p463, 466-467.

H2O2. (n.d.). *Introduction to hydrogen peroxide*. Retrieved on October 4, 2002 from www.h2o2.com/index.html

Hanovia Ltd. (December 1996). Disinfection system uses UV light technology. *Dairy Industries International, 61*(12), p41.

Hill, Stuart. (n.d.). *Lecture 2: basic microbial techniques*. Retrieved on November 4, 2002 from: www.bios.niu.edu/hill/bios213/lecture2.html

Hunter, B.T. (January 1999). Keeping Cut-Produce Safe. *Consumers' Research Magazine, 82*(1), p 8-9.

Izu, Kunio, Osamu Yamamoto, and Masakazu Asahi. (2000). Occupational skin injury by hydrogen peroxide. *Dermatology, 201*, p61-64.

Lorence, Julie. (September 1999). Sterilisation using hydrogen peroxide. *Pharmaceutical Manufacturing Review*, *11*(3), p10-12.

McDonnell, Gerald. (September 2002). Sterile environment. *Manufacturing Chemist.* 69-71.

MedNets: A medical search engine and health portal. (n.d.). *Toxicology and poisoning: hydrogen peroxide*. Retrieved October 4, 2002 from: www.mednets.com/index.cfm/fuseaction/

Melrose Chemical Ltd. (n.d.). *Cleaning and disinfection in the food processing industry*. Retrieved on November 4, 2002 from: http://www.melrosechem.com/english/publicat/general/cleaning.pdf

MSDS HyperGlossary. (June 2002). *Permissible exposure limits; air*. Retrieved on October 9, 2002 from: www.ilpi.com/msds/ref

NIOSH. (1997). *Pocket guide to chemical hazards.* Cincinnati, OH: NIOSH Publications.

Occupational Safety and Health Administration (OSHA). (n.d.). *Occupational safety and health guideline for hydrogen peroxide*. Retrieved October 4, 2000 from: www.osha-slc.gov/SLTC/healthguidelines/hydrogenperoxide/recognition.html

Rutala, William, and David Weber. (Mar/Apl 2001). New disinfection and sterilization methods. *Emerging Infectious Diseases, 7*(2), 348-354.

SilverPlatter Information. (n.d.). TLV: Threshold Limit Values. Retrieved on October 9, 2002 from: www.silverplatter.com/catalog/out/DOSE/TLV.html

SKC. (November 2002). *Color Diffusion Tubes*. Retrieved on November 7, 2002 from: http://www.skcinc.com/diffusion/diffusion.html

Vinquiry, Inc. (n.d.). *Material safety data sheet.* (Available from Vinquiry, Inc., 7795 Bell Road, Windson, CA 95492)

Walsh, Lawerence. (2000). Safety issues relating to the use of hydrogen peroxide in dentistry. *Australian Dental Journal, 45*(4), 257-269.

Zienolddiny, S., Ryberg, D., & Haugen, A. (2000). Induction of microsatellite mutations by oxidative agents in human lung cancer cell lines. *Carcinogenesis, 21*(8), 1521-1526.

Appendix A

Previous Hydrogen Peroxide Monitoring Values

Hydrogen Peroxide Testing Analysis

Date	Time	Area Sampled	Concentration	Comments
8/14/2002	3:40 p.m.	Inbetween T1 and T2	< 1.0 ppm	T2 running, T1 in sterilization
8/15/2002	6:00 p.m.	Inbetween T1 and T2	< 1.0 ppm	T2 running, T1 down
8/20/2002	7:00 a.m.	Inbetween T1 and T2	1.0 ppm	Both lines running
8/27/2002	4:00 p.m.	Overall, around both lines	> 1.0 ppm	Estimated at 1.50 ppm T1 running, T2 down
8/27/2002	4:08 p.m.	Overall, around both lines	> 1.0 ppm	Estimated at 1.50 ppm T1 running, T2 down
8/27/2002	4:20 p.m.	Near incline conveyor	1.0 ppm	T1 stopped, T2 running foil
8/27/2002	4:25 p.m.	Operator station, inbetween lines	1.0 ppm	T1 stopped, T2 running foil
8/28/2002	7:10 a.m.	By T1 incline conveyoer	1.0 ppm	T1 running, T2 sterilizing surge
8/28/2002	7:15 a.m.	Operator station, near T1	> 1.0 ppm	Estimated at 1.50 ppm Operator filling T1 H202 bath T2 sterilizing on surge
8/28/2002	7:20 a.m.	Operator station, near T1	> 1.0 ppm	Estimated at 1.25 ppm T1 running, top of bath sealed T2 sterilizing on surge
8/28/2002	7:55 a.m.	By T1 operator station	> 1.0 ppm	Estimated at 3.0 ppm T1 running, T2 spraying out tunnel (C3 sterilization) (T1 shut down, area evacuated)
8/28/2002	8:25 a.m.	By T1 operator station	> 1.0 ppm	Estimated 2.50 ppm T1 down, T2 completing sterilization (Area still evacuated) Area under T2 filler washed down
8/28/2002	8:55 a.m.	By T1 operator station	< 1.0 ppm	T1 down, T2 floor washed down. T2 down
8/28/2002	2:55 p.m.	Operator stations, between lines	1.0 ppm	Both lines running
8/28/2002	3:00 p.m.	T2 Operator area	1.0 ppm	Both lines running
8/29/2002	3:05 p.m.	By incline conveyor discharge	1.0 ppm	Both lines running. Supervisor tightened down bolts on top of bath
8/30/2002	9:10 a.m.	By operator stations, between lines	< 1.0 ppm	T1down, then began to run. T2 CIP filler cleaning
9/4/2002	6:45 a.m.	Inbetween both lines	< 1.0 ppm	Both lines in operation.

9/4/2002 5:15 p.m.	Inbetween both lines	< 1.0 ppm	T1 running. T2 beginning sterilization
9/6/2002 8:35 a.m.	Inbetween both lines	1.0 ppm	T2 running. T1 in operation but not currently running. Floors were washed down.
9/6/2002 10:55 a.m.	Inbetween both lines	est. 1.5 ppm	Both lines running
9/6/2002 11:00 a.m.	T2, door #6, rear of machine	est. 3.0 ppm	To identify leak point. Both lines running.
9/6/2002 11:05 a.m.	T2, in front of bath	est. 2.5 ppm	To identify leak point. Both lines running
9/6/2002 11:10 a.m.	Inbetween both lines	est. 2.0 ppm	Both lines running C' clamps installed on door #6's
9/6/2002 11:45 a.m.	Inbetween both lines	est. 1.5 ppm	Both lines running S. Senor recommended evacuating the area
9/9/2002 4:05 a.m.	Inbetween both lines	1.0 ppm	T1 operating. T2 preparing for tunnel sterilization
9/9/2002 9:10 a.m.	Inbetween both lines	1.0 ppm	T1 running. T2 donw for CIP cleaning. Door #6 on each line clamped to seal.
9/10/2002 5:15 p.m.	Operator's stations between lines	est. 3.0 ppm	T1 in production mode but down. T2 in tunnel sterilization.
9/10/2002 5:40 p.m.	Operator's stations between lines	est. 3.0 ppm	T1 down. T2 completed tunnel sterilization
9/11/2002 4:45 p.m.	Inbetween both lines	est. .02 ppm	T1 in clean-up. T2 running
9/12/2002 8:10 a.m.	Operator's stations between lines	est. 2.0 ppm	T1 running production mode
9/12/2002 8:30 a.m.	Operator's stations between lines	est. 1.5 ppm	Both lines in operation but not in active production
9/13/2002 8:45 a.m.	Inbetween both lines	est. 1.5 ppm	Both lines running. Exhaust fan was off at time. Turned fan on.
9/13/2002 9:15 a.m.	By operator's stations between both lines.	est. 1.2 ppm	Both lines in operation. Exhaust fan running.
9/13/2002 9:55 a.m.	By T1 and T2 incline conveyors	1.0 ppm	Both lines running.
9/17/2002 7:10 a.m.	Inbetween both lines	< 1.0 ppm	Both lines running
9/17/2002 8:30 a.m.	Inbetween both lines	1.0 ppm	Both lines in operation
9/19/2002 11:55 a.m.	Operator's stations between lines	est. 1.5 ppm	Both lines in operation.

9/19/2002 12:00 p.m.	Inbetween both lines	est. 1.5 ppm	T1 running. T2 down for jam in Jones cartoner. Informed B. Fox R. Carlson, M. Scharlau, M. Bostrom, M. Schoeder of situation and recommended evacuation of area or at least by operator's stations (moving employees nearer to Jones cartoner. Floors were washed down on both lines
9/20/2002 6:00 a.m.	Inbetween both lines	.05 ppm	Both lines running. T2 down for clean-up at time
9/24/2002 6:40 a.m.	Inside shoulder forming area, T1	est. 5.0 ppm	Initial reading elevated
9/24/2002 6:45 a.m.	Insider shoulder forming area, T1	est. 1.5 ppm	Levels dissipated
9/24/2002 6:50 a.m.	Inbetween both lines	1.0 ppm	Both lines running. Floor fans off, exhaust fan on
9/24/2002 10:30 a.m.	Inbetween both lines	est. 2.0 ppm	Both lines in operation. Exhaust fan was running Inlet fans were re-directed
9/24/2002 10:40 a.m.	Inbetween both lines	est. 1.5 ppm	Both lines in operation.
9/24/2002 5:15 p.m.	Inbetween both lines	1.0 ppm	T1 running. T2 in C3 mode Exhaust fan on, floor fans off
9/25/2002 9:00 a.m.	Inbetween both lines	1.0 ppm	Both lines running. Exhaust fan not on at time of test.
9/27/2002 6:40 a.m.	Inbetween both lines	1.0 ppm	Both lines in operation. Floor fans turned off
9/27/2002 9:30 a.m.	Inbetween both lines	< .01 ppm	Both lines down for cleaning
9/30/2002 2:30 p.m.	Inbetween both lines	< 1.0	Both lines completed C3 stage, ready for production, not in operational mode. Door #6 on both lines had tape along edges. H202 monitoring indicated continued high levels along the edges
9/30/2002 2:45 p.m.	Inbetween both lines	est. .05 ppm	T1 in production. T2 ready for production, not running. Attempted to calibrate monitor to tubes: tube read .05 ppm, monitor read 1.0 - 1.3 ppm
10/1/2002 4:30 p.m.	Inbetween both lines	est. 1.4 ppm	Both lines running. Exhaust fan was off at time. Fan was turned on following test. Outside of Door #6 on both lines was taped along edges. High levels

			of H202 continued to persist along the edges
10/1/2002 4:55 p.m.	Inbetween both lines	1.0 ppm	Exhaust fan was running since last test
10/2/2002 4:50 p.m.	Inbetween both lines	est. .50 ppm	Both lines running. Water spray under T1
10/3/2002 8:50 a.m.	Around both lines	1.0 ppm	Both lines running. Exhaust fan running
10/9/2002 2:50 p.m.	Inbetween both lines	est. .50 ppm	T1 cleaning surge. T2 in production
10/16/2002 6:40 a.m.	Between both lines	est. .70 ppm	Both lines in production
10/16/2002 3:00 p.m.	Between both lines	est. .80 ppm	Both lines in production
10/17/2002 10:35 a.m.	Inbetween both lines	est. .90 ppm	Both lines running
10/21/2002 3:10 p.m.	Around both lines in front of inline conveyors	est. .80 ppm	Both lines completed sterilization Neither line running
10/30/2002 1:15 p.m.	Around and between both lines	est. 1.2 ppm	Both lines running. Corrective measures taken following test include turning on exhaust fan and washing down floors
10/30/2002 5:35 p.m.	Between both lines	est. 1.2 ppm	Both lines running
10/31/2002 3:55 p.m.	Around and between both lines	.50 ppm	Both lines running

Appendix B

Company XYZ Hydrogen Peroxide Standards/Procedure

HYDROGEN PEROXIDE FUME INVESTIGATION

Date: ________________ **Time:** ______________ **a.m. / p.m.**

Individual Reporting High Level Vapor: ______________________________

Location of Vapor: _________________________

Individual Notified: __________________________ **Time:** __________ **a.m. / p.m.**

Dräger Detector Pump Reading near suspected high level area: __________________

1.0 ppm (parts per million)	**Take no action**
>1.0 ppm but <1.5 ppm	**30 minutes to reduce the ppm to 1.0**
>1.5 ppm	**Shut down line and evacuate area**

Corrective or preventative action taken: ____________________________________

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Note any repairs made; contact individuals in the work area affected providing them with information regarding the investigation and actions taken. Have them sign the form below.

____________________________ ____________________________

____________________________ ____________________________

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Area Supervisor's Signature: ______________________ **Date:** _________

Subject:

Hydrogen Peroxide Fumes

File Name: proced/hydrogen.doc

Issue Date: 12/15/94

Nature of Last Revision: *Revision #:*

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Filler Operator Desks Master
A Adco B Certipack D Adco

This procedure addresses the issue of high hydrogen peroxide vapor, who's responsible for taking the test, the procedure which must be followed, and possible causes.

Responsibility

Any individual trained to use the "Drager" testing unit may check the level.

Procedure

If high hydrogen peroxide fumes are suspected, the following procedure must be followed:

1. Immediately test the hydrogen peroxide vapor level near the area of suspected high levels.
2. Note the time and location of the test on the Filper downtime sheet.
3. If the part per million (ppm) is 1.0 or less, take no action.
4. If the level is above 1.5 ppm, shut the lines down & evacuate the area.
5. If the ppm is greater than 1.0 and 1.5 or less, notify the supervisor on shift. *At this point, we have 30 minutes to reduce the ppm to 1.0 ppm or less or shut down the lines and evacuate the area.*
6. Test the level after 30 minutes, or prior to the line starting back - up. If the level is 1.0 or less, either continue to run or start - up, respectively.

Possible Causes

1. Cover material vacuum tubes (liquid) are out of adjustment, vacuum motor not running, or the cover material is threaded wrong.
2. Cover material squeegee rollers have too little pressure, are open or worn.
3. Styrene squeegee rollers have too little pressure, are open or worn.
4. Vacuum tubes next to the seal die are not working.
5. Outside air blowers are off, not bringing in fresh air.
6. The temperature or humidity is too high.
7. The exhaust fans (2) in the Special Products Room are off.